Program of Energy Research and Development

at

Environment Canada:

2001-2003

A Two-Year Review

The Program of Energy Research and Development at Environment Canada

Environment Canada's participation in PERD provides the information needed to identify and respond to existing and emerging environmental challenges. PERD directly supports Environment Canada's focus towards sustainable development, mitigation of climate change, and innovation.

Diversifying Canada's Oil and Gas

Strategic Intent 1: Fulfil federal government responsibilities while maximising economic benefits and reducing environmental consequences from the expansion and diversification of Canada's oil and gas production

Strategic Direction 2: Provide S&T to extend and diversify Canada's oil and gas production from offshore and northern regions through the development of the science and technology needed for standards and regulations, and to reduce costs and mitigate environmental and safety concerns

Objective 1.2.1: Offshore Environmental Factors (OEF)

PROJECTS:

Offshore Wind and Wave Design Criteria
Objective: Develop methodologies to reliably determine offshore wind and wave design criteria

Data Assimilation into Coupled Atmosphere–Ocean Wave Models
Objective: Focus on research and development of high space-time resolution wave models for use in hindcast studies and forecasting of near-shore ocean waves

Operational Ice Modelling
Objective: Improve the safety of offshore drilling operations through improved CIS (Canadian Ice Service) sea ice and iceberg analyses and forecasts

Operational Detection of Icebergs from Space-Borne SAR
Objective: Develop the capability of routinely used remotely sensed data to detect and monitor icebergs off Canada's East Coast

Objective 1.2.2: Northern Hydrocarbon Production

PROJECTS:

Minimizing Environmental Risk from Petroleum Exploration in the Lower Mackenzie River Valley of the Northwest Territories
Objective: Reduce the risk of environmental damages resulting from the use of sumps in connection with exploration for oil and gas

Objective 1.2.3: Marine Transportation and Safety (MTS)

PROJECTS:

Prediction of Small Glacial Mass Distributions
Objective: Improve the safety of energy transportation (shuttle tankers) by developing better iceberg and bergy bit models and products

Strategic Direction 3: Provide S&T to address cross-cutting environmental and safety issues to support the production of Canada's onshore and offshore oil and gas resources

Objective 1.3.1: Flaring Research Initiative

Objective: Quantify flare efficiency and investigate design and operational factors to improve flare efficiency

Objective 1.3.3: Soil and Groundwater Remediation

PROJECTS:

Natural Wetlands-Containment, Transformation and Remediation of Toxic Organics from Natural Gas Condensates and Process Chemicals
Objective: Determine the effectiveness of wetlands in attenuating toxic contaminants

Remediation of Naphthenic Acids in Subsurface Soils and Groundwater at Oil Refineries
Objective: Determine the factors controlling the fate and transport of toxic naphthenic acids to soil and groundwater at oil production facilities

Groundwater Research Program (USDOE)
Objective: Examine the transport and fate of waste streams generated by natural gas processing operations

The Role of Sulfate Reduction in the Bioremediation Technologies for Hydrocarbon Contamination in Groundwater
Objective: Investigate the role of sulfate reduction in the natural attenuation of hydrocarbon contaminants in groundwater and investigate the ways to enhance this anaerobic biodegradation process

Remediation of Hydrocarbon-Contaminated Sites by Monitored Natural Attenuation (MNA)
Objective: Understand how attenuation processes work in different situation sto better predict the most suitable areas that lend themselves to this approach in a timely fashion

Assessment of Phytoremediation as an In-Situ Technique for Cleaning Oil Contaminated Sites
Objective: Explore the utility of plant based remediation of sites impacted by total petroleum hydrocarbons (TPH) and under presented prairie ecozone conditions and provide a data base of plants found to tolerate and remediate TPHs

Biological Barriers in Fractured Bedrock
Objective: Reduce permeability and prevent migration of contaminants in a fractured media by injecting a carbon source to stimulate the groundwater bacteria

Solar Detoxification of Groundwater
Objective: Provide new technology (solar energy based) for the remediation of groundwater contaminated with petroleum hydrocarbons

In-Situ Soil Flushing for the Remediation of Hydrocarbon Contaminated Soil
Objective: Develop an enhanced in-situ soil flushing process for the simultaneous removal of organic contaminants and heavy metals

Attenuation of an Ethanol/BTEX Plume in Fractured Bedrock Model Undergoing Biostimulation
Objective: Address the increasing addition of ethanol in gasoline as an oxygenate and its effects on bioattenuation processes in groundwater

Standardization and Validation of Terrestrial Toxicity Test Procedures for Assessing Biological Effects in Hydrocarbon Contaminated Soils
Objective: Develop, standardize and field validate terrestrial toxicity tests relevant to Canadian sites

Assessment of Natural and Anthropogenic Impacts of Oil Sands Contaminants within the Northern River Basin
Objective: Assess the environmental impact of natural vs. anthropogenic hydrocarbon release

Land Farming of Bioremediated Hydrocarbon Contaminated Soils/Wastes
Objective: Establish a new site using bioremediated hydrocarbon contaminated soils to develop a best management practice for handling bioremediated hydrocarbon contaminated soils

Toxicity Workshop
Objective: Identify priorities for method development, validation and standardization that will lead to a second generation of soil toxicity test methods for assessing the effects of contaminated soils

Cleaner Transportation for the Future

Strategic Intent 2: Foster cleaner sustainable transportation fuels and systems in order to improve the environment, reduce emissions, including GHGs, and to increase economic activity through development of domestic and export markets

Strategic Direction 1: Provide S&T to reduce emissions from transportation sources to improve air quality and health and reduce GHG production

Objective 2.1.1: Air Quality-Particles Research

PROJECTS:

Characterization of Particulates and Precursors in Emission
Objective: Contribute to improvement of air quality models by addressing knowledge gaps and providing data for model development and evaluation

Characterization of Particles in Ambient Air
Objective: Gain new insights into the transport, transformation and fate of ambient fine particles and their precursors particularly those produced by emissions from the transportation sector

Objective 2.1.2: Advanced Fuels and Transportation Emissions Reduction (AFTER)

PROJECTS:

Engine Cold Start Efficiency
Objective: (completed) Conduct R&D on technologies and/or processes that have the potential to reduce energy consumption and use energy more efficiently

Measurement of Toxic Emissions from Ethanol/Gasoline Blend Fuels
Objective: Develop the data that is necessary to assess the environmental and health benefits of ethanol when used in light duty vehicles in Canada

Environmental Properties of Ether Fuels
Objective: Screen potential diesel ethers for environmental concerns related to water and soil, measure environmental properties of diesel ethers (water solubility) and measure environmental toxicity of potential candidate ethers

Windsor Workshop Support
Objective: Exchange of technical information on transportation fuels

Strategic Direction 2: Provide S&T to improve energy efficiency, reduce emissions and provide economic benefits to Canada from next generation vehicles and systems

Objective 2.2.2: Fuel Cells, Electric and Hybrid Vehicles

PROJECTS:

Measurement of Toxic Emissions from Fuel Cells, Electric, and Hybrid Vehicles
Objective: Expand on the characterization of emissions from fuel cells, electric and hybrid vehicles with the focus on a fuel cell project, a diesel-electric hybrid bus project and a Transport Canada project

Objective 2.2.4: Optimisation of the Energy Efficiency of Transportation Systems

PROJECTS:

The St. Lawrence Routing Management Support Model
Objective: Produce models and prototypes indexing safety and efficiency factors for safe, efficient waterway routing. Increase public awareness

Energy Efficient Buildings and Communities

Strategic Intent 3: Reduce the overall energy intensity of Canada's buildings and community systems and, consequently, their associated GHG emissions while, at the same time, providing Canadian companies with potential economic opportunities

Strategic Direction 2: Provide S&T to integrate energy services (supply and end use) in communities to reduce overall energy requirements, optimise the use of available resources and reduce environmental impacts including GHG emissions

Objective 3.2.4: Energy Management for Sustainable Communities

PROJECTS:

Design of More Effective Energy Storage Systems
Objective: Develop a variety of tools and procedures for implementing Underground Thermal Energy Storage (UTES), an advanced form of ground source heat pumping in Canada and to deliver the knowledge and tools that will allow the construction, operation and management of energy from thermal networks

Development of Energy from Waste Technologies and other Alternative Technologies
Objective: Demonstrate microturbine technology for energy production, provide the ability to compare environmental impacts from a variety of waste management systems options, advance and demonstrate the concept of bioreactors for optimised energy recovery

Integrating Urban Forestry, Green Roofs and Vertical Gardens to Reduce Energy Consumption
Objective: Evaluate the potential of using green roofs, vertical gardens and urban forestry to reduce residential summer energy consumption through reductions in canopy level temperatures and shading

Clean Air OnLine
Objective: Develop new and innovative ways to use existing web based tools and identify additional tools required to support community action for cleaner air

Energy Efficient Industry

Strategic Intent 4: Reduce the overall energy intensity of Canada's industrial sectors and, consequently, their associated GHG emissions while, at the same time, improving productivity and providing Canadian companies with potential economic opportunities

Strategic Direction 3: Provide S&T to advance generic energy related technologies and processes to reduce energy intensity, particularly in industry, to achieve productivity gains and reduce GHG emissions and other wastes

Objective 4.3.3: Research, Development and Deployment for industrial Separation and Refrigeration (SEPREF)

PROJECTS:

Applications of Microwave–Assisted Processes (MAP) to Solvent–less Synthesis and to Low Solvent, Energy-Efficient Extraction
Objective: Provide Canada's synthesis and extraction industrial sector with low solvent and low energy consuming processes

Canada's Electricity Insfrastructure

Strategic Intent 5: Reduce the environmental impacts of Canada's electricity infrastructure, particularly greenhouse gases, through alternative electric power generation, increased efficiency of fossil-fueled plants and strategies to capture and manage emissions

Strategic Direction 1: Provide S&T to increase the proportion of Canada's electricity supply from renewables and distributed systems which offer improved system integration and reduced environmental impacts. (R&D activities in this area will exclusively address generic technological issues whose applications are not related to communities, buildings and industry)

Objective 5.1.1: Electricity from Renewable Energy Technologies

PROJECTS:

EC Wind and Solar Energy Resource Assessment- Solar Radiation
Objective: Provide spectral irradiance data for the PV industry in anticipation of new ISO standards on PV efficiency

EC Wind and Solar Energy Resource Assessment- Wind Mapping with Atmospheric Models
Objective: Improve wind forecasts to benefit de-regulated electrical energy markets, and optimise siting and power production of renewable energy systems through improved wind energy resource assessment information

Strategic Direction 2: Provide S&T to reduce emissions and the associated environmental impacts from centralised combustion based electric power generation systems

Objective 5.2.1: Characterisation of Canadian Fuels and their Emissions (COFE)

PROJECTS:

Environmental Contaminants in Coal and Coal By products
Objective: Characterise contaminants in coal feed stocks, stack emissions and in the environs of major power plants

Objective 5.2.2: Clean and Efficient Combustion Technologies for Large Utility Electricity Generation

PROJECTS:

Prevention, Control and Mitigation of Pollution from Stationary Combustion Sources
Objective: Understanding and minimising the environmental and health impacts of fossil fuel electricity generation

Objective 5.2.3: CO_2 Capture and Storage

PROJECTS:

Coal Bed Methane Field Pilot-Characterization of Injected CO_2 and Impact on CBM
Objective: Reduce GHG emissions by subsurface injection of carbon dioxide into deep coalbeds and to assess the technical feasibility of CO_2 disposal while enhancing coal bed methane production

Climate Change

Strategic Intent 6: Minimize the negative impacts of climate change on the Canadian energy sector

Strategic Direction 1: Provide S&T to support the Canadian energy sector's response to the impacts of climate change

Objective 6.1.1: Climate Change Impacts on the Energy Sector (CCIES)

PROJECTS:

Historical and Future Climate for the Assessment of Energy Sector Impacts in Canada
Objective: Develop a national set of energy sector historical and future climate scenarios, develop an energy sector scenario and guide the research community and users, and engage the energy sector in updating their chapter of the Canada Country Study based on historical and future climate scenarios

Impacts of Climate Changes in the Canadian Inland Seas Watershed on the Canadian Energy Sector
Objective: Develop a regional climate model for Northeastern North America, develop the predictive capability for extreme climate events in the inland seas watershed, produce climate change scenarios and support for the energy sector regarding environmental predictions

Climate Change and Offshore Design Criteria
Objective: Determine long term trend and variability in wind, wave and storm climatology

Impacts of Evolving Ice Conditions on the Energy Sector
Objective: Provide detailed assessment and interpretation of recent sea ice cover trends over Canadian marine areas of importance to hydrocarbon development and transportation

Critical Aspects of Changes in Sea Ice Cover on Energy Production
Objective: Provide an indication of how sea ice conditions will evolve over the next 25 years

Canadian Participation in FIREIII/SHEBA
Objective: Contribute to knowledge of climate modelling, particularly in relation to arctic climate processes and changes

Climate Change Impacts on Cold-Regions Hydrologic Processes and Extreme Events Associated with the Hydro-Electric and Oil/Gas Industries in Western and Northern Canada
Objective: Improve the understanding of the climatological and hydrological factors that affect energy production and transmission of hydro-electric power in western Canada, and oil and gas development in northwestern Canada

Critical Aspects of the Climate o Western Canada for the Energy Industry
Objective: Provide detailed assessments and interpretations of the capabilit simulate climatic conditions over s areas of western Canada of importance to the energy industry

Snow Water Equivalent Variations in Western Canada and Climate Ch Related Impacts for Hydropowe Production
Objective: Create and analyse a 20-year time series of snow water equivale basins in western Canada that are important to hydropower production to provide a baseline for future chang develop scenarios to predict future changes on hydropower operations, and conduct a first assessment to inco satellite-derived SWE into regiona modelling

Changes in Cloud Cover over N America for Solar Energy Development in Canada
Objective: Provide information on impacts of climate change on the availability of solar energy in Canada

Climate and Energy in the Toron Niagara Region: Integration of Science and Policy
Objective: Assessment of the impa climate, vulnerabilities to climate and adaptive strategies to deal with the associated risks and opportunities Toronto-Niagara Region

Strategic Direction 2: Provide S& enhance the natural uptake of GH the atmosphere

Objective 6.2.1: Enhancement of Greenhouse Gas Sinks (EGGS)

PROJECTS:

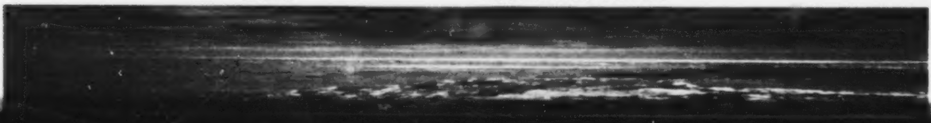
Estimation of Terrestrial CO_2 So and Sinks in Canada
Objective: Data acquisition to impr modelling of biospheric–atmosphe exchange processes

Wetlands in the Forest Context Sink Potential
Objective: Improve techniques for estimating the carbon budget of C managed and unmanaged forest and forest wetland ecosystems and identify trends and changes in carbon sequestration associated with fore management, land use change and climate variability and change

Impact of Variability and Climate Change on Carbon Sequestratio Boreal Deciduous Forest
Objective: Characterise variability in boreal forest carbon and water budgets and understand factors of carbon sequestration over several annual

Wetlands in the Agricultural Con Carbon Sink Potential
Objective: Improve methodology understand processes, evaluate management practices and improv update models of GHG fluxes from agroecosystems in order to quantify carbon sequestration and provide verifiable carbon credit accounting

Advice, Coordination and Asses
Objective: Ensure effective deliver POL outputs and a mechanism for advising policy makers of scientific research results as needed for nat and international negotiations and policy development with respect to GHG and climate change



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Program of Energy Research and Development at Environment Canada

2001–2003

A Two-Year Review

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March 2004

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ISBN 0-662-37831-8
Cat. No. En 14-2/2003E

Overview

Environment Canada has been an active participant in the federal Program of Energy Research and Development (PERD) since 1977. Together with other federal departments, universities, and industry sectors, EC through PERD has contributed to finding sustainable energy development solutions for the benefit of Canadians.

EC manages a diverse research and development portfolio funded by PERD, leading on the delivery of environmental science and technology initiatives specific to energy. EC leads in a number of areas such as: flaring, groundwater and soil remediation, particulate matter, sustainable community development, bioprocesses, and the enhancement of greenhouse gas sinks. In addition, EC managers have contributed their expertise to a myriad of other initiatives ranging from weather prediction–to cumulative effects of toxics–to alternative energy technologies. This participation has led to the advancement and sharing of knowledge in technologies, and will also contribute to ensuring sustainable development in northern and frontier regions.

Science and technology efforts under PERD have been world class, supporting decision-making, policy development, and regulatory activities; contributing to the development of national standards and guidelines; supporting public safety; and environmental needs.

Through PERD, EC has developed a high level of expertise which has led to the advancement of knowledge in a number of Business Line priority areas allowing for timely advice on emerging and existing issues.

This report highlights Environment Canada's involvement in PERD for 2001–2003. Section 1 points out how EC's energy research and development activities jointly benefit both the Department and PERD mandates. Section 2 outlines ECs current involvement in PERD at the project level with emphasis on successful partnerships, leveraging, and technology transfer efforts.

For information concerning the direction of PERD at Environment Canada, please refer to a companion document entitled "Program of Energy Research and Development at Environment Canada: Building Partnerships for the Future," to be published in 2004.

Acknowledgements

We would like to thank the Environment Canada managers for their contributions to this document and NADEC Experts and Consultants Inc. for their production work.

Survol

Environnement Canada (EC) est un participant actif au Programme de recherche et de développement énergétiques (PRDE) du gouvernement fédéral depuis 1977. Grâce à sa collaboration avec d'autres ministères fédéraux, des universités et des secteurs de l'industrie, la recherche menée à EC, laquelle est financée par le PRDE, a contribué à mieux comprendre les effets sur l'environnement découlant de l'utilisation des sources d'énergie traditionnelles et de la découverte de nouvelles sources d'énergie renouvelables.

EC mène divers projets de recherche et de développement qui sont financés par le PRDE, et le ministère est un chef de file dans plusieurs secteurs de recherche tels que le brûlage à la torche, la restauration des eaux souterraines et des sols, les matières particulaires, le développement durable des collectivités, les bioprocédés et l'amélioration des puits de gaz à effet de serre. Les gestionnaires d'EC ont apporté leur expertise à une multitude d'initiatives allant de la prévision météorologique à l'effet cumulatif des substances toxiques et aux technologies d'énergie innovatrices résultant en l'établissement de réseaux scientifiques et de réseaux d'échange de pratiques.

Les efforts de recherche et de développement qu'a déployés EC dans le cadre du PRDE ont été reconnus mondialement. Ils ont contribué à de saines prises de décisions en matière de politiques et de règlements et à l'élaboration de normes et de recommandations nationales, tout en répondant à des besoins en matière de sécurité et d'environnement.

Grâce au PRDE, EC a acquis une compétence de haut niveau, ce qui lui a permis d'approfondir ses connaissances dans plusieurs secteurs d'activités prioritaires, d'offrir des conseils opportuns sur des enjeux nouveaux ou existants.

Ce rapport souligne la participation d'EC au PRDE de 2001 à 2003. La section 1 contient un court résumé des avantages dont le ministère et le PRDE ont pu bénéficier à la suite de la participation des deux parties au PRDE. La section 2 décrit brièvement les projets auxquels EC participe dans le cadre du PRDE et souligne les réussites en ce qui a trait aux partenariats, à l'effet levier des différents projets et aux transferts de technologie.

Pour de plus amples renseignements sur le PRDE d'Environnement Canada, veuillez consultez le document d'accompagnement intitulé *Programme de recherche et de développement énergétiques d'Environnement Canada : Créer des partenariats pour l'avenir*, à paraître en 2004.

Remerciements

Nous désirons remercier les gestionnaires d'Environnement Canada pour leur contribution au présent document et la société NADEC Experts - Conseils Inc. pour son travail de production.

Table of Contents

Overview / Acknowledgements iii

Survol / Remerciements iv

List of Tables vii

Acronyms ix

Introduction

Environment Canada—Leading Science to Protect our Environment 1
  Sustainable Development 1
  Climate Change 2
  Innovation 2
What is PERD 2
Management and Funding at PERD 3
PERD at Environment Canada 5
Research at Environment Canada— A Partnership with PERD 5

Profiles by Strategic Intent

Strategic Intent 1—Oil and Gas Sector 7

Strategic Direction 2 7
  Objective 1.2.1 Offshore Environmental Factors (OEF) for Regulatory, Design, Safety, and Economic Purposes. 7
  Objective 1.2.2 Northern Hydrocarbon Production 17
  Objective 1.2.3 Regulatory Requirements for the Safe and Efficient Transportation of Oil and Gas by Tankers, and for Other Occupational and Public Safety Standards 23

Strategic Direction 3 26
  Objective 1.3.1 The Regulation and Reduction of GHG and Other Atmospheric Emissions, Primarily from Flaring 26
  Objective 1.3.3 The Remediation of Groundwater and Soil Issues 28

Strategic Intent 2—Transportation Sector 59

Strategic Direction 1 59
  Objective 2.1.1 Support for the Development of Technological and Other Measures to Control and Reduce Emissions of Particulate Matter .. 59
  Objective 2.1.2 The Design and Use of Gaseous and Liquid Hydrocarbon Fuels and Associated Technologies to Achieve Emissions Reductions 65

Strategic Direction 2 71
  Objective 2.2.2 The Development of Fuel Cell, Electric, and Hybrid Vehicle Components and their Supporting Infrastructures. 71
  Objective 2.2.4 The Optimization of the Energy Efficiency of Transportation Systems. 75

Table of Contents

Table of Contents

Strategic Intent 3—Buildings and Communities Sector 79

Strategic Direction 2 79
    Objective 3.2.4 Energy Management for Sustainable Communities 79

Strategic Intent 4—Industry Sector 93

Strategic Direction 3 93
    Objective 4.3.3 The Development of Advanced Technologies and Products for Heat Management and Separation Including High Efficiency Drying 93

Strategic Intent 5—Electricity Sector 101

Strategic Direction 1 101
    Objective 5.1.1 Improving the Economics and Efficiency of Conversion of Renewable Energy to Electricity Including Related Storage, Hybrid, and Systems Technologies 101

Strategic Direction 2 106
    Objective 5.2.1 The Characterization of Canadian Fuels and their Emissions (COFE) for more Efficient and Environmentally Benign Electricity Generation 106
    Objective 5.2.2 The Conversion of Fossil Fuels to Electricity more Efficiently with Ultra-low Environmental Emissions 109
    Objective 5.2.3 The Capture, Treatment, Transport, Use, and Storage of CO_2 from Large Point Sources 114

Strategic Intent 6—Climate Sector 119

Strategic Direction 1 119
    Objective 6.1.1 The Development of a Better Understanding of the Impacts of Climate Change on the Energy Sector, Improvement in the Forecasting of those Impacts, and the Development of Some Possible Response Strategies 119

Strategic Direction 2 151
    Objective 6.2.1 The Development of a Better Understanding of the Relevant Natural GHG Cycles; and Steps to Increase the Net GHG Uptake from the Atmosphere by Forests, Agricultural Lands, and Oceans 151

Annex 1 POL Objective Leaders 167

Annex 2 Recent Presentations, Conferences, and Publications 169

Annex 3 Environment Canada Project Managers 207

Annex 4 List of Environment Canada's PERD Projects 211

List of Tables

1 Percentage of PERD Funds for POL 1.2.1 Allocated to Each Department. 8

2 Percentage of PERD Funds for POL 1.2.2 Allocated to Each Department. 18

3 Percentage of PERD Funds for POL 1.2.3 Allocated to Each Department. 24

4 Percentage of PERD Funds for POL 1.3.1 Allocated to Each of the Department. 27

5 Percentage of PERD Funds for POL 1.3.3 Allocated to Each Department. 29

6 Percentage of PERD Funds for POL 2.1.1 Allocated to Each Department. 60

7 Percentage of PERD Funds for POL 2.1.2 Allocated to Each Department. 66

8 Percentage of PERD Funds for POL 2.2.2 Allocated to Each Department. 72

9 Percentage of PERD Funds for POL 2.2.4 Allocated to Each Department. 76

10 Percentage of PERD Funds for POL 3.2.4 Allocated to Each Department. 80

11 Percentage of PERD Funds for POL 4.3.3 Allocated to Each Department. 94

12 Percentage of PERD Funds for POL 5.1.1 Allocated to Each Department. 102

13 Percentage of PERD Funds for POL 5.2.1 Allocated to Each Department. 107

14 Percentage of PERD Funds for POL 5.2.2 Allocated to Each Department. 110

15 Percentage of PERD Funds for POL 5.2.3 Allocated to Each Department. 115

16 Percentage of PERD Funds for POL 6.1.1 Allocated to Each Department. 120

17 Percentage of PERD Funds for POL 6.2.1 Allocated to Each Department. 152

Acronyms

Acronyms

AAFC	Agriculture and Agri-Food Canada
AAQD	Analysis and Air Quality Division
ACSYS	Arctic Climate System Study
ADM	Assistant Deputy Minister
AEIRB	Aquatic Ecosystem Impacts Research Branch
AES	Atmospheric Environment Service
AFTER	Advanced Fuels and Transportation Emissions Reduction
AFTER	Advanced Fuels and Transportation Emissions Reduction
AIRG	Adaptation and Impacts Research Group
AMDAR	Aircraft Meteorological Data Relay
AOP	Advanced Oxidation Process
AOP	Advanced Oxidation Process
ArcInfo	Software in field of environmental mapping for analysis and modelling
As	Arsenic
ASHRAE	American Society of Heating, Refrigerating, and Air Engineers
ATES	Aquifer Thermal Energy Storage
ATMS	Advanced Traffic Management Systems
ATOFLAMS	Atmospheric Time-of-Flight Laser Ablation Mass Spectrometry
Bap-	Benzo[a]pyrene
BART	Biological Activity Reaction Test
BEPS	Boreal Ecosystems Productivity Simulator
BEPS-INTEC	Boreal Ecosystem Productivity Simulator-Integrated Terrestrial Ecosystem C-budget model
BERMS	Boreal Ecosystem Research and Monitoring Sites
BIO	Bedford Institute of Oceanography
BIOCAP	Biosphere Implications for CO_2 Policy in Canada
BTEX	Benzene, Toluene, Ethyl-benzene, and Xylene
CAM	Canadian Aerosol Module
CANMET	Canada Centre for Mineral and Energy Technology
CAOL	Clean Air Online
CAPP	Canadian Association of Petroleum Producers
CBM	Coalbed Methane
CCAF–TEAM	Climate Change Action Fund, Technology for Early Action Measures
CCG	Canadian Coast Guard
CCIES	Climate Change Impacts on the Energy Sector
C-CLASS	Carbon-Canadian Land Surface Scheme
CCME	Canadian Council of Ministers of the Environment
C-CORE	Centre for Cold Ocean Research Engineering
CCRP	Climate Change Research Program
CCRS	Canada Centre for Remote Sensing
CCTEAF	Climate Change Technology Early Action Fund
CD	Companion Document
CEM	Community Energy Management
CEPA	Canadian Environmental Protection Act
CES	Community Energy Systems
CETC	CANMET Energy Technology Centre
CFCAS	Canadian Foundation for Climate and Atmospheric Sciences
CGCM1	Canadian General Circulation Model version 1
CH_4/CO_2	Methane/Carbon Dioxide
CHC	Canadian Hydraulics Centre
CHELASOL	Chelation/Solvent Extraction Process
CIS	Canadian Ice Service

Acronyms

Acronyms

CLASS model	Canadian Land Surface Scheme model
CLIMo	Climate Lake Ice Model
CLIVAR	Climate Variability and Prediction Program
CMHC	Canada Mortgage and Housing Corporation
CNOPB	Canada--Newfoundland Offshore Petroleum Board
CNSOPB	Canada--Nova Scotia Offshore Petroleum Board
CO	Carbon Monoxide
CO_2	Carbon Dioxide
COFE	Characterization of Canadian Fuels and their Emissions
CORONA	Consortium for Research on Natural Attenuation
CPPI	The Canadian Petroleum Products Institute
Cr	Chromium
CRB	Climate Research Brand
CRCM	Canadian Regional Climate Model
CRYSYS	Cryospheric System in Canada
CSA	Canadian Standards Association
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DEA	Diethanolamine
DEMs	Digital Elevation Models
DFO	Department of Fisheries and Oceans
DIAND	Department of Indian Affairs and Northern Development
DIPA	Diisopropanolamine
DMSP	Defense Meteorological Satellite Program
DND	Department of National Defence
DRECT	Demonstration of Resource and Energy Conservation Technology
DUC	Ducks Unlimited Canada
EAE	Environmentally Acceptable Endpoints
EBAD	Environmental Biotechnology Applications Division
EC	Environment Canada
ECES	Energy Conservation through Energy Storage
ECOSYS	Canadian ecosystem model
ECS	Environmental Conservation Service
EED	Emergencies Engineering Division
EERC	Energy & Environmental Research Center
EGGS	Enhancement of Greenhouse Gas Sinks
EGR	Enhanced Gas Recovery
ENVISAT	Environment Satellite
EOS	Earth Observing Systeme
EPF	Energy Priority Framework
EPIC	Environment Plastic Industry Council
ERAC	Environmental Research Advisory Council
ERMD	Emissions Research and Measurement Division
EROD	Ethoxyresorufin O-deethylase
ERS–2	European Remote Sensing Satellites
ESA	European Space Agency
ETB	Energy Technology Branch
ETC	Environmental Technology Centre
EV	Electric vehicle
FCM	Federation of Canadian Municipalities
FDM	Flight Data Monitoring
FIRE III	First ISCCP Regional Experiment -III (1994-1999)
FJMC	Fisheries Joint Management Committee

Fluxnet–Canada CO_2 flux network	A national university network integrating worldwide CO_2 flux measurements.
FRI	Flaring Research Initiative
GASREP	Groundwater and Soil Remediation Environmental Program
GCMs	Global Climate Models
GEM	Global Environmental Model
GEWEX	Global Energy and Water Cycle Experiment
GGFR	Global Gas Flaring Reduction
GHG	Greenhouse Gases
GIS	Geographic Information System
GRI/DOE	Gas Research Institute/Department of Energy
GSC	Geological Survey of Canada
GSM	Global System for Mobile Communications
HAPs	Hazardous Air Pollutants
HC	Health Canada
HEV	Hybrid Electric Vehicle
Hg	Mercury
HMDC	Hibernia Management Development Corporation
IBIS	Integrated Terrestrial Biosphere Model
IC	Industry Canada
ICS	Information and Communications Systems
IDS	Iceberg Detection Software
IEA	International Energy Agency
IEA-ECES	International Energy Agency Implementing Agreement
IGBP	International Geosphere-Biosphere Program
IGCC	Integrated Gasification Combined Cycle
IIC	International Ice Patrol
IIMI	Integrated Ice Management Initiative
IIP	International Ice Patrol
IJC	International Joint Commission
INAC	Indian and Northern Affairs Canada
IPCC	Intergovernmental Panel on Climate Change
ISCCP	International Satellite Cloud Climatology Project
ISO	International Organization for Standardization
ISWM	Integrated Solid Waste Management
IWM	Integrated Waste Management
JGR	Journal of Geophysical Research
k	Thousand
KNMI	Netherlands Meteorological Institute
LAMS	Laser Ablation Mass Spectrometry
LAOGMT	Lloydminster Area Operators Gas Migration Team
LARS-WG	Model to simulate time-series of a suite of climate variables at a single site
LFG	Landfill gas
LICOR	LI-COR Biosciences-designs and manufactures instrument
LIDAR	Light Detection and Ranging
LII	Laser-Induced Incandescence
LS	Lignosulfates
M	Million (i.e., $1x10^6$)
MAGS	Mackenzie GEWEX Study
MAM	Multispectral Atmospheric Mapping
MAP	Microwave-Assisted Processes
MC2	Mesoscale Compressible Community model
MDEA	Methyldiethanolamine

Acronyms

MEA	Monoethanolamine
MFO	Multi-Function Oxidases
MIPA	Monoisopropanolamine
MIROS	Microwave Remote Sensor for the Ocean Surface
MMT	Methylcyclopentadienyl Manganese Tricarbonyl
MOE	Microbial Oil Eater
MOU	Memorandum of Understanding
MRM	Multiresidue Method
MSC	Meteorological Service of Canada
MSC50	Meteorological Service of Canada: a 50-year continuous wind and wave hindcast for the North Atlantic
Mt	megatonnes
MTBE	Methyl Tertiary Butyl Ether
MTO	Ministry of Transportation of Ontario
MTS	Marine Transportation and Safety
NA	Naphthenic Acids
NARCM	Northern Aerosol Regional Climate Model
NDMA	N-Nitrodimethylamine
NEB	National Energy Board
NEI	Northern Ecosystem Initiative
Ni	Nickel
NIC	National Ice Center
NOMAD	Navy Oceanographic Meteorological Automatic Device
NO_x	nitrogen oxides
NRBS	Northern River Basins Study
NRC	National Research Council of Canada
NRCan	Natural Resources Canada
NRCC	National Research Council of Canada
NRCM	Northern Aerosol Regional Climate Model
NREI	Northern Rivers Ecosystem Initiative
NSERC	Natural Sciences and Engineering Research Council of Canada
NSIDC	National Snow and Ice Data Centre
NWP	Numerical Weather Prediction models
NWRI	National Water Research Institute
O_2	Oxygen
OCC	Overland Custom Coach
ODS	Ozone-depleting substances
OECD	Organisation for Economic Cooperation and Development
OEF	Offshore Environmental Factors
OERD	Office of Energy Research and Development
OFFN	OFFN: NARCM without CAM
OGP	Internal Association of Oil and Gas Producers on Energy Conservation through Energy Storage
ONN	NARCM with CAM
PAC	Polycyclic Aromatic Compounds
PAD	Peace-Athabasca Delta
PAHs	Polycyclic Aromatic Hydrocarbons
PCBs	Polychlorinated Biphenyls
PCP	Partners for Climate Protection
PCSP	Polar Continental Shelf Project
PERD	Program of Energy Research and Development
Pg	Picogram
PM	Particulate Matter
PMG technology	Permanent Magnetic Generator technology

POL	Program at the Objective Level
PTAC	Petroleum Technology Alliance Canada
PV	Photo-Voltaic
PWGSC	Public Works and Government Services Canada
R&D	research and development
RADARSAT	Radar Satellite
RBCA	Risk-based Corrective Action
RCM	Regional Climate Modelling
RSI	Radarsat International
RTDF	Remediation Technology Development Forum
RWDI	Rowan Williams Davies and Irwin Inc.
S&T	Science and Technology
SAIC	Science Applications International Corporation
SAR	Synthetic Aperture Radar
SDSM	Spatial DownScaling Model
SEPREF	Separation and Refrigeration
SETAC	Society of Environmental Toxicology and Chemistry
SHCP	Solar Heating and Cooling Programme
SHEBA	Surface Heat Budget of the Arctic Ocean
SMMR	Scanning Multichannel Microwave Radiometer
SNTHERM	Snow Thermal model (A process driven, one dimensional energy and mass-balanced model to calculate snow melt and other snowpack fluxes)
SOC	Southampton Oceanography Centre
SO_x	sulphur oxides
SRC	Saskatchewan Research Council
SRES	Special Report on Emissions Scenario
SRM	Snowmelt Runoff Model
SSM/J	Special Sensor Microwave/Imager
SSR	Surface Solar Radiation
STECA	Statistical Tool for Extreme Climate Analysis
STRICE	Measurements of Structures in Ice
SWE	Snow Water Equivalent
SWS-2	Storm Wave Study -2
	systems for plant biology, biotechnology, and environmental research
t	Tonne (metric)
TC	Transport Canada
TEA	Triethanolamine
TES	Thermal Energy Storage
TIE	Toxicity Identification and Evaluation
TNR	Toronto-Niagara Region
TPH	Total Petroleum Hydrocarbons
TRT	Thermal Response Test
TSRI	Toxic Substance Research Initiative
UFORE	Urban Forest Effects
UON	NARCM with CAM and UCAR CSM data as lateral boundary condition
USDOE	United States Department of Energy
USEPA	United States Environmental Protection Agency
UTES	Underground Thermal Energy Storage
VOC	Volatile Organic Compounds
WATCLASS	Waterloo Canadian Land Surface Scheme
WATFLOOD	Waterloo Flood Forecasting model
WCRP	World Climate Research Program
WGCC	Working Group on Coupled Climate Modeling

Introduction

Introduction

Environment Canada- Leading Science to Protect our Environment

Environment Canada's mandate is to "preserve and enhance the quality of the natural environment". Through it's mandate, Environment Canada is serving the best interests of all Canadians. It is in partnership with other federal departments, industry, universities and through international collaborations that EC achieves its goals. Three critical areas have been identified by Environment Canada as it's focus for the coming years (*2003-2004 Estimates: Report on Plans and Priorities*). These areas are:

- Reduce the Health and Safety Impacts of Environmental Threats
- Sustain Our Natural Environment
- Move Forward on Climate Change

The document entitled *2003-2004 Estimates: Report on Plans and Priorities* reveals the specific actions by which Environment Canada will help achieve the broad goals of the Government of Canada in instituting **sustainable development**, mitigating **climate change**, and incorporating an **innovative approach**. The document is intended to serve, over the next three years, as a functional framework around which concrete results will manifest. Environment Canada is strongly committed to partnerships and innovative strategies as tools by which to accomplish its aims.

Sustainable Development

Sustainable development is a complex issue that resonates from local to global arenas. The concerted efforts of individual Canadians, corporate citizens and governments of all stripes will be needed to achieve this end. The Sustainable Development Strategies (SDS) now required of all departments, set a positive example through which our government provides corporate leadership. At a macro level, sustainable development is clearly a basic tenet of environmental stewardship. Environment Canada is focussed on becoming the leader in this area. In a statement of basic values the department asserts:

- **Our vision** is to see a Canada where people make responsible decisions about the environment and where the environment is thereby sustained for the benefit of present and future generations.
- **Our mission** at Environment Canada is to make sustainable development a reality in Canada by helping Canadians live and prosper in an environment that needs to be respected, protected and conserved.

Given the resources and experience of the department, and the skills and focus of its people, leadership in sustainable development is a natural objective for Environment Canada.

Introduction

Climate Change

Climate change concerns are subsumed in the issue of sustainable development. Climate change is the most readily recognizable end product of unenlightened economic growth. An effort to mitigate climate change is a step toward sustainable development.

Canada's Climate Change Plan is being co-managed by the Minister of the Environment and the Minister of Natural Resources. The mandate and normal bailiwick of each of these federal departments provide an intrinsic affinity with the issue and a vested interest in a successful outcome. A total of $3.7 billion has been allotted to the enterprise in order to meet our pledge to reduce GHG emissions by 240 million tonnes, on average, through the first Kyoto Accord commitment period of 2008–2010.

Innovation

Innovation is not a commodity that can be produced on demand. Rather, it is the flowering of a process through which it is nurtured in a supportive milieu. The Government of Canada is determined to foster conditions in which innovation becomes commonplace. Environment Canada has embraced this approach.

Innovation and partnership are the twin pillars that will provide solutions to the issues facing Environment Canada and our country as a whole. Innovation will lead to the development of the eco-efficient products and processes needed to achieve sustainability at home, and will give Canadian businesses an advantage in the newly emerging environmental products industry.

The **Program of Energy Research and Development or PERD** offers the possibility to institute sustainable development, mitigate climate change and incorporate innovation.

What is PERD?

The Program of Energy Research and Development is a federal energy research and development program that focuses specifically on Canadian energy issues and their impact. Environment Canada's focus towards ***sustainable development, mitigation of climate change and innovation*** is directly supported by PERD. Through its funding, PERD helps EC advance its objectives in an environmentally sound manner, delivering on the mission of the department by helping Canadians live and prosper in an environment that is protected and conserved.

Environment Canada's participation in a program such as PERD provides the information needed to identify and respond to existing and emerging environmental challenges. Moreover, these activities serve as a basis for the formulation of environmental policies needed to achieve sustainable development. PERD activities support the development of new environmental technologies to prevent and remediate environmental pollution.

- PERD is dedicated to "fund research and development designed to ensure a sustainable energy future for Canada in the best interests of both our economy and our environment."

Introduction

- PERD is a vector through which funding can flow, with a mandate to support non-nuclear energy research and development.

- PERD is providing funds to interdepartmental activities that are working to provide solutions for Canada's energy priorities, such as reducing greenhouse gas emissions, improving the energy efficiency of our homes, offices and industries, finding practical, affordable alternate sources of energy, developing cleaner, more efficient transportation vehicles and systems, ensuring the integrity of Canada's energy infrastructure, and providing economic opportunities for Canada's energy-related industries.

- PERD is a direct support for 40% of all non-nuclear energy research and development at or above the provincial government level in Canada.

- PERD is a direct support towards the efforts of a wide variety of stakeholders interested in the advancement of energy research and development.

- PERD is an active partnership with government research facilities at all levels, with universities, with corporate entities, and with other interested organizations and associations. It draws together and augments the strengths of many groups toward a common goal.

- PERD is a source of solutions that embodies the best qualities of government in responding to arising energy issues by bringing to bear the resources of a broad spectrum of interested parties. It bypasses the drawbacks inherent to unilateral efforts and benefits from the positive synergistic effect of combined strengths and the creative consensus building potential of diverse organizations. Additionally, this strategy provides for fiscal responsibility by foregoing duplication of effort and seeking to fund excellence in research wherever it is found.

- PERD is ideally positioned to play a positive supporting role in the energy interests of numerous organizations including advancing the social, economic and environmental agendas of Environment Canada. In the broadest sense, the unique attributes of PERD ensure that the Environment Canada–PERD partnership effectively contributes energy solutions to compliment the goals of the Government of Canada vis-à-vis the priority issues of our day.

Management and Funding at PERD

Like many other programs within the federal government, PERD has moved from an activity-based program to a results-based management (RBM) framework. This structure helps PERD be more flexible and responsive to Canada's dynamic energy priorities to ensure a sustainable future.

In 1999, the Assistant Deputy Minister (ADM) of NRCan's Energy Sector recognized the need to restructure the program to form a better link between energy sector policies and science and technology investments. The approach incorporated performance measurement and evaluation within the framework, essential to more effectively monitor progress and increase the level of accountability to deliver results. In addition, the RBM structure lends itself to increased interdepartmental collaboration specifically because the projects are grouped under common areas within the Program at the Objective Level (POL).

The RBM logic model links POL outputs to higher level outcomes and longer term impacts. An evaluation process is built into this model in which each year, one quarter of the POLs in the overall program are reviewed. In this evaluation, external reviewers determine if the outputs have been achieved and if any outcomes are attributed to those achievements. Once the evaluation has been performed, a second review attempts to shape the framework of priorities for the next term of POLs. This review process determines the allocation of funds, as well as the creation, termination, expansion, and merging of POLs that suit the current Energy Priority Framework (EPF).

The EPF, developed by the Energy Sector of NRCan, summarizes the current energy priorities facing Canada. In response to these priorities, the S&T Companion Document (CD) supplements the EPF by defining six strategic intents that describe the broad directions of NRCan's non-nuclear energy S&T activities. Strategic intents are divided according to major priorities called strategic directions, with each strategic direction having one or more long-term objectives. Environment Canada participates in projects under all six **Strategic Intents:**

- **Diversifying Canada's Oil and Gas**
- **Cleaner Transportation for the Future**
- **Energy-efficient Buildings and Communities**
- **Energy-efficient Industry**
- **Canada's Electricity Infrastructure**
- **Climate Change**

Since the document "Program of Energy Research and Development of Environment Canada 1999-2001—A two year review" was published a few changes have occurred within EC's participation in the PERD program. Firstly, EC has now become a participant in the Northern Hydrocarbon Production POL 1.2.2. Secondly, the newly created "Energy Management for Sustainable Communities" POL 3.2.4, to which EC actively participates, has brought together participants and projects that made up two former POLs, Energy Systems for Sustainable Community Development (3.2.3) and Community Energy Systems (3.2.1). The new POL 3.2.4 now takes a more global approach to community-level energy use.

PERD at Environment Canada

Although the activities of PERD are conducted primarily under the auspices of Natural Resources Canada, the Program funds energy research and development interests in eleven other federal departments and sub-agencies. Environment Canada's allotment of the total PERD funding budget makes the Department the second largest participant in the Program.

Environment Canada is a key player in the PERD program, leading the delivery of environmental science and technology specific to energy issues with quite a diverse portfolio. Environment Canada manages 58 PERD projects, contributing to 17 of the 33 program objectives (POLs) under PERD and to all six strategic intents. Environment Canada has been actively involved with PERD since 1977 and significant benefits have accrued to Environment Canada's three science based Business Lines (i.e., Clean Environment, Nature, and Weather and Environmental Predictions).

Research at Environment Canada- A Partnership with PERD

Environment Canada is a science-based department. Science is the fundamental tool used to deliver on the promise of the department's vision and mission statements. The scientific method is used to understand the processes by which our environment functions. Research provides the baseline against which policy actions are measured and upon which sound decisions concerning future initiatives are made. The quality of the scientists and of the research at Environment Canada are world class. The department understands the advantages of the horizontal approach in managing emerging issues and is, now more than ever, committed to considering economic and social issues in conjunction with its environmental initiatives. It is eager to partner with like minded departments and agencies.

The sources and methods we use to produce energy and the nature of the technologies we employ to exploit it are central to the issues of sustainable development and climate change. Energy production, transmission and use are the largest source of GHG emission in Canada. The simple acts of driving vehicles and heating buildings are major GHG sources. In addition, the production and transportation of energy introduces significant non-GHG contamination into our environment. The most cost-effective avenue to sustainability is found in increasing the efficiency of energy use and production. Before we achieve our desired environmental goals, the energy sector will undergo a significant transformation.

PERD is adept at finding and supporting projects that are providing innovation in the energy sector. PERD is dedicated to provide quality research on topics related to energy and the environment, and to the advancement of a Canadian economic advantage. It acts horizontally in concert with many interested parties. PERD is poised to contribute to the efforts of Environment Canada in each of the three areas of concentration delineated in the, "2003-2004 Estimates: Report on Plans and Priorities." It becomes therefore obvious that the Environment Canada–PERD partnership was inevitable. Hereafter are presented some PERD projects within Environment Canada that have or will significantly contribute to the realization of Environment Canada priority initiatives.

Profiles by Strategic Intent

Oil and Gas Sector

Offshore Environmental Factors

Profiles by Strategic Intent

The following section describes the programs at the objective level (POLs) in which EC participates and gives a brief overview of the EC projects involved in those POLs.

Strategic Intent 1—Oil and Gas Sector

Strategic Intent 1 is to fulfill federal government responsibilities while maximizing economic benefits and reducing environmental consequences from the expansion and diversification of Canada's oil and gas production.

Strategic Intent 1 · Strategic Direction 2

Strategic Direction 2 provides S&T to extend and diversify Canada's oil and gas production from offshore and northern regions through the development of the science and technology needed for standards and regulations, and to reduce costs and mitigate environmental and safety concerns. Priority will be given to R&D related to new sources of natural gas.

Strategic Intent 1 · Strategic Direction 2 · Objective 1.2.1

Offshore Environmental Factors (OEF) for Regulatory, Design, Safety, and Economic Purposes.

POL 1.2.1—Offshore Environmental Factors (OEF)
The work of this POL contributes to ensuring the safe, efficient, and economical extraction of natural hydrocarbon resources in harsh offshore environments. The OEF POL is a group of coordinated research initiatives from several federal departments that support the development of tools, techniques, methodologies, and basic scientific understanding required to address the design, operational and regulatory needs of the oil and gas industry off Canada's east coast and in the north. The research helps fulfill government departmental mandates in support of energy and sustainable development; improves the ability to make timely and economical engineering decisions and regulatory approvals; and helps ensure human safety and environmentally safe oil and gas operations. The meteorological monitoring responsibility of EC extends from providing accurate weather information to all Canadians to working within the mandates of this POL. Through the Weather and Environmental Predictions business line, EC provides weather information for the safe exploitation of our offshore energy reserves as well as to all Canadians.

Some highlights within this POL and lead by EC include work on reducing the uncertainty in wind and wave design criteria off the east coast of Canada. A 49-year database of wind and wave hindcasts has been achieved and is continuously updated. It is used extensively by industry in several east coast offshore projects. Another project is MIROS (Microwave Remote Sensor for the Ocean Surface), to be used to measure wind and wave intensities. It's reliability is being tested in severe storm conditions. Overall, it is expected that the reliability of wind and wave forecasts will increase and that some savings in operating costs might be realized. In order to improve safety and efficiency of hydrocarbon extraction operations in ice-infested waters, EC excels towards development of models to predict and detect movements of icebergs and changes in sea ice; these are improved upon, tested and modified on a continuing basis.

Research projects are coordinated efforts by federal laboratories from EC, DFO, NRC, and NRCan. These projects also include close collaboration with Canadian (MUN, University of Calgary, University of Ottawa, Dalhousie University,) and various international agencies and universities (Southampton (U.K.) Oceanography Centre and the Bedford Institute of Oceanography, Oxford University), industry (e.g. Oceanweather Inc.), the OGP, private contractors, other federal departments (PWGSC, DND, Canadian Space Agency) and U.S.-based federal laboratories.

The following activities are included under POL 1.2.1:

- Wind- and Wave-Hindcasting and Forecasting
- Sea ice and Iceberg Detection and Forecasting
- Ocean Current Measurements and Circulation Modelling
- Ice-Structure Interaction Research and Standard Setting
- Seabed Stability Research and Development
- Basin Assessment Research

The OEF POL has established various international partnerships. Multinational oil and gas industries are now collaborating with this POL in three new partnerships in order to facilitate current measurements in Atlantic offshore. Collaborative work between the Canadian and the European Space Agencies involve satellite imagery to enhance safety and efficiency of marine operations in ice-infested waters. Cooperation continues between CIS and IIC (International Ice Patrol) in the exchange of iceberg data and European Ice Services. The CHC advises the European Union Framework Program 5 project "STRICE". Many universities also participate in various ways with the OEF POL either by exchange information or joint projects.

For 2001-2002, the POL plan included 20 individual projects of one- or two-year duration. For 2002-2003, 18 individual projects of two- to four-year duration were in progress. In 2002-2003, POL 1.2.1 was in its first year of a four-year POL Plan. EC is leading 4 of these projects.

The total 2001-2002 annual budget for POL 1.2.1 was $5,554,000, and $6,595,000 for 2002-2003. The total PERD resources available for 2001-2002 were $2,732,000 and for 2002-2003, $2,682,000. PERD funds were divided amongst the departments involved in this POL (see Table 1.). For this POL, the leverage quotient of total resources to PERD resources for 2001-2001 was 2.0 and for 2002-2003, 2.5.

Table 1. Percentage of PERD Funds for POL 1.2.1 Allocated to Each Department

Department	Percentage of Funds (%)	
	2001–2002	2002–2003
NRCan	34.6	31.7
EC	23.0	21.1
NRC	21.3	21.1
DFO	19.8	24.8
POL Coordination EC	1.3	—
POL Coordination DFO	—	1.3

Environment Canada Projects for POL 1.2.1

Offshore Wind and Wave Design Criteria

Project Manager: Val Swail

Project Objectives

This project is a continuation of a previous PERD project investigating wind and wave design criteria. This project is closely linked to the *Climate Change and Offshore Design Criteria* project in POL 6.1.1. Previous versions dealt only with hindcasts of a small set of storms, with attendant uncertainty in the estimates. Recent advances in global reanalyses, interactive kinematic analysis techniques developed by this project, and advances in computing technology have allowed for continuous hindcasts, including shallow water effects, of 50 years duration, greatly reducing the uncertainty in design estimates.

This project has been coordinated through two PERD Technical Working Groups, the Canadian National Waves Committee and the Working Group on Marine Winds. The work is also closely coordinated with the International Association of Oil and Gas Producers (OGP) MetOcean Committee, which represents the technical expertise for all of the world's major oil companies; project goals, objectives and results are presented regularly to this Committee, at their regular meetings and at specialized symposia. The member companies of the OGP have contributed significantly to this project, particularly in the development and testing of the wind/wave hindcast methodology. Other collaborators in the project include the Southampton (U.K.) Oceanography Centre and the Bedford Institute of Oceanography on the topic of measurement uncertainties in ship, platform and buoy winds. BIO is also an important partner in the development of advanced wave models, particularly related to extreme storms. The hindcast work is done in collaboration with Oceanweather Inc., who have many years experience in all of the world's ocean basins, for government and the oil and gas industry.

This project also provides the critical data bases for work carried out in a PERD project in the Climate Change Impacts on the Energy Sector on the impacts of potential climate change on future design criteria.

The objective of this project is to develop methodologies to reliably determine offshore wind and wave design criteria. This project addresses a broad spectrum of R&D activities between the basic research on winds and waves and the ultimate use of the information by regulators, code developers, design engineers and operators of exploration, production and transportation facilities offshore. The primary focus of this research project is on reducing the uncertainty in wind and wave design criteria off the east coast of Canada.

This project benefits EC because the long term continuous wind and wave hindcast data bases for the North Atlantic Ocean produced by this project represent the most important homogeneous data set available for determination of long term trend and variability in wind, wave and storm climatology, which is an important objective of the Climate Research Branch. The joint project with the Netherlands Meteorological Institute helps us to describe wind, wave and storm variability on a global basis.

Profiles by Strategic Intent

Oil and Gas Sector

Offshore Environmental Factors

Offshore Wind and Wave Design Criteria

Methodology

This research project has three important components: (1) to investigate the problems with specification of wind speeds due to measurement uncertainties in ship, platform, buoy and satellite winds which form the basis for the hindcast, and mesoscale features embedded in the synoptic scale flow which contribute additional energy; (2) to develop wind and wave hindcast methodologies incorporating those research results; (3) to develop, produce and disseminate reliable, up-to-date design criteria for winds and waves off the east coast of Canada.

Goals, Outputs and Project Success Story

- Revised wind-wave hindcast models and methodology (winds and waves) and procedures based on implementation of wind-wave research results (March 2005).
    1. Paper and presentation to 7th International Workshop on Wave Hindcasting and Forecasting on detailed analysis of tropical storm types (October 2002 - done)
    2. Journal paper on reliability of buoy wind speed measurements in high sea states (March 2003 - done)
    3. Interim report on SOC flow distortion study (March 2003 - done)
    4. Report on vertical wind profile study (October 2004)
    5. Paper on SAR wind analysis of coastal and mesoscale wind patterns (March 2005)
    6. Final report on SOC flow distortion study (October 2004)
    7. Paper and presentation to 8th International Workshop on Wave Hindcasting and Forecasting on MSC50 wind and wave hindcast (October 2004 - new)

- 50-year continuous wind-wave hindcast database (1956-2005) for the western North Atlantic on a ~50 km grid based on revised methodologies (March 2006).
    1. 47-year wind wave hindcast data base (March 2003 - done)
    2. Presentation to industry on 50-year hindcast (October 2003 - done)
    3. Completion of MSC50 wind and wave hindcast (March 2005 – new)
    4. Report on validation of 50-year hindcast, including 1-D and 2-D wave spectra (December 2005)

- Revised wind-wave design criteria based on additional years and revised methodologies, to industry, Boards for *Guidelines* (March 2006).
    1. Initial Web page online with hindcast, validation and design criteria information (March 2003 - done – to be updated routinely as additional information becomes available)
    2. Interim design criteria for east coast based on 47 year hindcast (March 2004)
    3. Presentation to industry on revised design information (October 2004)
    4. Organization of 8th International Workshop on Wave Hindcasting and Forecasting, (November 2004 – new)
    5. Development of Regional Annex for ISO 1990-1 Metocean design and operating considerations, for Canadian East Coast (October 2004 – new).

The 49-year database of high-quality continuous wind and wave hindcasts has been used extensively by industry in several east coast offshore projects during the year, including Petro-Canada, EnCan, Exxon/Mobil, Chevron/Texaco, Marathon and Shell, and by regulatory authorities in several Environmental Assessments. The users of the hindcast data bases have expressed considerable interest in using the updated versions as they become available, and eventually the second generation, high-resolution 50-year version, incorporating the additional research results, by 2005/06. The wind and wave hindcast results will, at the invitation of the industry, form the basis for the East Coast of Canada Regional Annex to the International Standard ISO/DIS 19901-1: Petroleum and natural gas industries – specific requirements for offshore structures: Part I: Metocean design and operating considerations.

Funding

The average resources allocated for this project per fiscal year were $595,000 (2001-2002; 2002-2003). An average 34.5% of these resources came from PERD funds, the rest came from other sources (A-Base, industry, others such as US Army, U. Southampton, Oxford U., Oceanweather Inc., Netherlands Met. Inst). The average leverage quotient of total resources to PERD resources for the project was 2.9.

Data Assimilation into Coupled Atmosphere-Ocean Wave Models

Project Manager: Laurence Wilson

Project Objectives

This project is a scaled down version of an earlier PERD project aimed at the development of a fully integrated coupled atmosphere-ocean wave data assimilation and short range forecast modeling system. The present project focuses on research and development of high space-time resolution wave models for use in hindcast studies, and forecasting of near-shore ocean waves.

The objectives of this project are:

- To ensure the availability of a state-of-the-art, high quality wave models for operational use in wave hindcasting and forecasting;
- To improve marine wind forecasting and analysis;
- "….investigation of extreme mesoscale features; exploitation of remote sensing capabilities; improvements to longer lead-time forecasts and forecast products";
- "….forecasts of wave spectra; investigation of tropical storms, particularly as they become extra-tropical with major impacts for both design and prediction (a particularly troublesome east coast Canadian problem). It was the consensus of the workshop that research and development on design and prediction of environmental parameters continues to be an important priority for the sustainable, cost effective, environmentally responsible and safe development of offshore oil and gas, in the short medium and long term."

This project benefits EC by ensuring that state-of-the-art ocean wave models are fully validated in Canadian waters and are made available in a form that is useable in MSC operations. This results in more accurate wave forecasts and analyses for Canadian waters.

Methodology

Model development and validation; comparative evaluation of model performance for extreme wave cases in Canadian waters.

Goals, Outputs and Project Success Story

- A new high resolution version of the wave model fully validated and prepared for operational use has been completed. CMC is presently implementing the model. Research has turned to the evaluation of high resolution, near shore, shallow water algorithms in preparation for the next generation of wave models;
- Studies of extreme storms: Model performance on January 2000 and January 2002 storms has been evaluated. Performance of the new version of the operational model and of research models designed for near shore shallow water wave simulation is in progress. We are using Hurricane Juan as a case for evaluation, and have obtained high quality wind analyses to drive the wave models;

- Full coupling of the wave model with the operational atmospheric model is in progress. The goal of this part of the project is to ensure consistency between the structure of WAM and the atmospheric model, and to include realistic two-way physical feedback between the surface winds and the ocean waves;

- International intercomparison project: This has essentially been completed with the publication described below, but data is still collected regularly by the international team;

- Wind data assimilation: Little work has been done on this part of the project because of funding constraints. A small project to determine wind error correlation statistics for east coast marine areas was completed in 2002.

Results of recent PERD-funded research into the international wave model WAM have led to the implementation of a new upgraded version of this model for use in operational wave forecasting in MSC. Implementation of this model has been accepted by CMC, based on the results of the research carried out. This results directly in more accurate daily wave forecasts for East and West coast waters.

Continual intercomparison of wave forecasts from operational wave models have shown the Canadian model to be competitive with wave forecast models in other meteorological services over several years. These results were published in the journal Weather and Forecasting.

Funding

The average resources allocated for this project per fiscal year were $261,350 (2001-2002; 2002-2003). An average 50.3% of these resources came from PERD funds, the rest came from other sources (A-Base). The average leverage quotient of total resources to PERD resources for the project was 2.0.

Operational Ice Modelling

Project Manager: Tom Carrières

Project Objectives

This project has been in progress since 1987. A project managed by BIO (Bedford Institute of Oceanography) on coupled ice-ocean modeling and the *Operational Ice Modeling* project are very strongly linked in that the models and research from the BIO project are implemented to support CIS operations through the CIS project. The main objective of this project in the context of PERD is to improve the safety of offshore drilling operations through improved CIS sea ice and iceberg analyses and forecasts.

This project benefits EC through its improved models and applications of models to improve the reliability and accuracy of CIS ice information services.

Methodology

The main focus of the project is to identify new research results and models and to implement them operationally at CIS. The focus of industry has been on iceberg models but coupled ice-ocean model development has also been a key factor since ocean currents are the single most important driver for iceberg drift.

Goals, Outputs and Project Success Story

As an ongoing project the overall goal has been to improve CIS products. In a very similar vein to NWP, the improvements are ongoing. Overall the project continues to be on-target and keenly focused on industry needs. The biggest success story has been the industry acceptance and use of the CIS iceberg model. An interface allows industry to input iceberg observations and provides them with forecasts of the iceberg's trajectory. This has become an instrumental aspect of their iceberg management operations. The other main success has been the close collaboration between BIO and CIS and the growing international linkages with US governments (IIP and NIC) and with European ice services.

Funding

The average resources allocated for this project per fiscal year were $452,500 (2001-2002; 2002-2003). An average 44.8% of these resources came from PERD funds, the rest came from other sources (A-Base, industry, others such as IIP). The average leverage quotient of total resources to PERD resources for the project was 2.2.

Operational Detection of Icebergs from Space-Borne SAR

Project Manager: Dean Flett

Project Objectives

This project was originally proposed and accepted in 1999/2000. The current project and work is an extension of the original project proposal. This project is not done as part of a bigger project or program within the federal government. However, the work undertaken in this project is closely linked to and directly benefits to and from an industry-led program entitled, the Integrated Ice Management Initiative (IIMI). Much of the IIMI work is being done by or led by C-CORE of St. John's, with whom this PERD project work closely. The IIMI is a large and comprehensive program spanning the spectrum of ice management R&D in support of oil and gas operations off Canada's east coast.

By developing the capability to routinely use remotely sensed data, particularly RADARSAT Synthetic Aperture Radar (SAR) data and in the future ENVISAT and RADARSAT-2, to detect and monitor icebergs off Canada's East Coast, the CIS will improve its ability to issue more complete, timely, and accurate iceberg warnings and forecasts, as well as expand the utility of RADARSAT and make more effective and complete use of the data.

Since icebergs are a continuing hazard for marine activities, this meets the Environment Canada objective to minimize risks to life and property. Improved iceberg analyses and forecasts also meet the PERD objective to enhance the predictive capability of marine environmental parameters that have a direct bearing on human safety and sound operations.

Methodology

The overall methodology applied in this project involves the collection and validation of iceberg target information (location, size, shape, etc.) against the target information derived (either manually or automatically) from the SAR image data. Algorithm and software development is done in parallel to implement and refine detection algorithms to automatically detect and discriminate the iceberg targets from other valid targets (e.g. ships) or erroneous targets. Thresholds and probabilities are developed for different SAR beam modes (e.g. resolution, incidence angle) and environmental conditions (e.g. wind speed, sea state) using the validation data and are used to refine the algorithms. As advanced SAR capabilities continue to come available (e.g. multiple-polarization and polarimetry), these capabilities are assessed to improve the automated detection and discrimination. The automated detection systems are/have been integrated into the CIS data processing and analysis environment and are tested and evaluated for operational utility and usability to augment the existing data sources used to carry out the iceberg monitoring program.

Goals, Outputs and Project Success Story

The project has resulted in the successful integration of the IDS (Iceberg Detection Software), developed by C-CORE specifically to comply with CIS information technology architecture and data processing flow. A scientific report clearly summarizing the capabilities of RADARSAT-1 for iceberg detection and specifying the optimal beam modes was recently presented to the CIS. In addition, the IDS has been enhanced to handle Envisat ASAR data, including the multiple polarization beam modes. Initial testing with multi-polarization ASAR data indicates promise for improving ship vs iceberg discrimination.

The success of this project is that, C-CORE, the prime contractor and developer supported through this project, in conjunction with support from IIMI and the European Space Agency (ESA), has taken the results from the last 5 years and is offering a "SAR Iceberg Detection Service". Oil and gas companies as well as the International Ice Patrol have used SAR-derived information to support their activities in the past 2-3 years. This coming season, in 2004, C-CORE will be delivering services to these entities as well as the CIS, using Envisat ASAR data provided through their ESA-supported "Northern View" program.

Funding

The average resources allocated for this project per fiscal year were $125,250 (2001-2002; 2002-2003). An average 27.2% of these resources came from PERD funds, the rest came from other sources (A-Base, industry, other such as CSA funding to CIS, European Space Agency). The average leverage quotient of total resources to PERD resources for the project was 3.7.

Profiles by Strategic Intent

Oil and Gas Sector

R&D in Aid to Regulatory Requirements

Strategic Intent 1 · Strategic Direction 2 · Objective 1.2.2

Carry out R&D in aid to regulatory requirements for the eventual production of oil and gas in the north.

POL 1.2.2—Northern Hydrocarbon Production

Hydrocarbon exploration activities are rapidly progressing in the Northwest Territories as the oil industry moves north along the Mackenzie Valley into the Delta and over the next several years into the Beaufort nearshore. Interest is also growing for sedimentary basins in the Yukon and in Nunavut, in particular in the Arctic Archipelago and the northeastern Continental Margin. In the past, exploration activities were the main focus and resulted in the ability to cope with short term explorations but not necessarily long term development activities. Science and technology is currently the focus of the Northern Hydrocarbon Production POL Plan, as it relates to identifying and mitigating environmental, geotechnical and engineering constraints to northern hydrocarbon development (exploration and production).

Some of the highlights of this POL from projects led by various departments, include an extensive record of ice ridging and thickness that is continuous since April 1991; an extensive knowledge of these factors is essential in order to understand marine hazards in hydrocarbon development. A multi-tasked prototype of the ice-profiling sonar has been developed with collaboration of ASL Environmental Sciences Inc. Natural gas hydrates contain a source of highly concentrated natural gas in the form of methane. Gas hydrates are found in sub-oceanic sediments in polar regions (shallow water) and in continental slope sediments (deep water) where pressure and temperature conditions make it stable. Many new insights were gained on gas hydrates in the Mackenzie Delta such as the stability of the occurrence of free gas in contact with gas hydrates and the occurrence of gas hydrates within permafrost; this is the first extensive production testing of a gas hydrate deposit. A project led by EC is gathering critical information in order to reduce the risk of environmental damages resulting from the use of sumps in connection with exploration for oil and gas in the Lower Mackenzie River Valley of the Northwest Territories. Maps, guides and data will indicate areas where the use of sumps should be avoided.

An advisory committee leads the identification and investigation of constraints to hydrocarbon development. This committee has representatives from the oil industry, National Energy Board, Inuvialuit First Nation, and five government departments: Natural Resources Canada, Indian and Northern Affairs Canada, Fisheries and Oceans Canada, Environment Canada and the National Research Council.

Funding sources and partners in the POL include several federal departments (NRCan, EC, DFO, Indian and Northern Affairs Canada), Canadian Museum of Nature, the Government of the Northwest Territories, the Inuvialuit Social Development Program, private industry, the Canadian Association of Petroleum Producers (CAPP), US Geological Survey, and the Canadian Space Agency.

The following activities are included under POL 1.2.2:

- Environmental Factors
- Goetechnical Factors
- Engineering Factors

For 2001-2002, the POL plan included 6 individual projects (environmental and geotechnical activities). For 2002-2003, 13 individual projects were conducted under Environmental Factors (6 projects), Gegotechnical Concerns (5 projects), and Engineering Factors (2 projects). In 2002-2003, POL 1.2.2 was in its first year of a new four-year POL plan. EC is leading one of these projects started in 2002 under the environmental activities.

The total 2001-2002 annual budget for POL 1.2.2 was $9,174,000. The budget was unavailable for 2002-2003. The total PERD resources available for 2001-2002 were $455,000 but were unavailable for 2002-2003. PERD funds were divided amongst the departments involved in this POL (see Table 2). For this POL, the leverage quotient of total resources to PERD resources for 2001-2002 was 20.2.

Table 2. Percentage of PERD Funds for POL 1.2.2 Allocated to Each Department

Department	Percentage of Funds (%)	
	2000–2002	2002–2003
NRCan	62.6	N/a
DFO	32.1	N/a
EC	—	(40,000)
POL Plan administration	5.3	N/a

Environment Canada Projects for POL 1.2.2

Minimizing Environmental Risk from Petroleum Exploration in the Lower Mackenzie River Valley of the Northwest Territories

Project Manager: Laura Johnston

Project Objectives

The project did not stem from a previous PERD initiative. The project was initiated in 2002/03 to address concerns regarding the apparent lack of success of long term containment of wastes within in-ground sumps. The primary objective of the project is to reduce the risk of environmental damages resulting from the use of sumps in connection with exploration for oil and gas. It focuses on the management of drilling mud and liquid wastes from camps, as these are the major waste streams produced during petroleum exploration. The knowledge and tools developed will focus on the production of maps, guides and data sets to indicate areas where the use of sumps should be curtailed and/or avoided because there may be a significant risk of failure. The project comprises 4 phases: Phase 1 was a feasibility study to determine if constraints maps could be produced for the Mackenzie Delta. Phase 2 was to refine the existing work from a specific focus on constraints mapping to determine the spatial data required to aid in decision making. Phase 3 was to focus on coordinating data collection, scientific studies and field work to collect and analyze data to develop a preliminary constraints mapping model. Phase 4 is expected to result in the development of a user controllable mapping tool.

The key benefit of this project to both Environment Canada and other stakeholders is the coordination, development, publication and distribution of meaningful scientific information (research and data) necessary to develop and implement environmental management strategies that minimizing the environmental risk from petroleum exploration in the lower Mackenzie River valley of the Northwest Territories.

Goals, Outputs and Project Success Story

The project has led to the development of critical partnerships. It has influenced the development of research projects and data acquisition initiatives that will provide the necessary information to develop a constraints mapping tool. Key partners to the success of this project include:

- Government of the Northwest Territories;
- Department of Indian Affairs and Northern Development
- Natural Resources Canada
- Mackenzie Delta Producers Group (Industry)
- Dr. Kevin Biggar, University of Alberta
- Steve Kokelj, Doctorate Fellow, Carleton University

Phase 1 (2002/2003)

Conduct a project to determine the feasibility of developing constraints maps for Mackenzie Delta. The goal was to develop a map-based tool to help reduce the risk of environmental damages resulting from industrial activities. The resulting maps were to be designed for use by government agencies, regulators, industry and communities to ensure the sustainability (balance of environment and economic concerns) of this industry. The specific goals of the assessment were to:

- Document the methodology associated with the development of constraints maps for the region;
- Conduct a data review of existing digital datasets and on-going data gathering initiatives to identify usable datasets and document existing data gaps;
- Develop a preliminary set of matrices to serve as a 'straw model' for subsequent review and discussion purposes; and
- Detail the tasks required to develop constraints maps for the region and recommend a plan of action.

After review of the data available for the Mackenzie Delta area, it became apparent that only small scale (low level of detail) mapping exists for the majority of the study area. This scale of data is less than optimal for the generation of constraints maps and therefore further effort expended to assemble the information and develop constraints mapping matrices was not considered feasible in the short term. It was however, determined that a comprehensive data review detailing the environmental conditions of the delta would be an invaluable tool for the environmental management of the region. In addition to the review of existing data, it was also identified that data gaps and current related research projects be thoroughly documented and data collection priorities and protocols be developed.

Phase 2 (2003/2004)

To refine the existing work from its focus on constraints mapping to determine what spatial data are required to make informed environmental management decisions. The deliverable for Phases 1 and 2 (spring 2004) will be a report which includes a discussion of the following topics:

- An overview of the current environmental conditions in the Mackenzie Delta. The preliminary topics for review include but are not limited to the following:
    - Climate
    - Physiographic
    - Hydrology, Hydrogeology, Limnology and Coastal Processes
    - Soils and Permafrost
    - Vegetation
    - Wildlife

- A breakdown of the environmental parameters and sensitivities that are involved with industrial development and activities within the delta. This would include an identification of the risk factors and their significance for the environment and industrial development.
- Details will be provided on:
    - What environmental variables are to be considered
    - Why these variables are important
    - What data is available and/or should be collected for the variables
    - Data collection standards (e.g., attributes and scale). This would be the first step in defining a minimum data specification for data collection towards the goal of formalizing the data collection process.
    - Alternative data collection methods that provide possible solutions to data gaps. This would include the comparison of remote sensing technology (satellite imagery, air photos and LIDAR). Discussion concerning the pros and cons of different methods will be provided including an estimate of associated costs.
    - Relevance to the assessment of the industrial developments.
- A review of the spatial data available and, where possible, privately held datasets would be detailed.
- A review of northern contaminant transport issues and research relating to risk of containment failure of past, present and future drilling waste disposal sites
- A review of current field research being conducted relating to Northern permafrost conditions

Phase 3 (2004/2005)

Phase three will focus on coordinating data collection, scientific studies and field work to collect and analyze the appropriate data required to develop a preliminary constraints mapping model.

A workshop of Northern researchers will be coordinated to develop a research strategy and develop data collection methodologies to address knowledge and data gaps/inconsistencies. This step is key to ensuring meaningful data is acquired in the future to refine constraint mapping models.

Currently, a working group (external to the current project) is proposing a project to develop a digital elevation model for the Mackenzie Delta. As this parallel project could play a key role in providing high resolution base data necessary for the development of constraint maps, Environment Canada has worked to influence the technical specifications to ensure the data collected will be capable of producing high resolution environmental feature and constraint maps. If funding is approved and data acquisition is completed by August 2004, the current project will use the new data in combination with information gathered from the initial phases of the current project to develop a constraints mapping model. Work will focus on developing output for a small test case area to help examine the feasibility of carrying out the work and to develop accurate cost estimates for completing the project on a broader scale.

Phase 4

Develop user controllable Internet based GIS mapping tool which uses refined risk assessment model to display scalable maps and data sets over the chosen area. User manual, data identification (meta data) and user instructions must be Internet based.

Funding

The average resources allocated for this project per fiscal year were $271,800 (2002-2003 only). An average 80.0% of these resources came from PERD funds, the rest came from other sources (A-Base). The average leverage quotient of total resources to PERD resources for the project was 1.3.

Strategic Intent 1 · Strategic Direction 2 · Objective 1.2.3

Regulatory Requirements for the Safe and Efficient Transportation of Oil and Gas by Tankers, and for the Other Occupational and Public Safety Standards.

Profiles by Strategic Intent

Oil and Gas Sector

Regulatory Requirements for Occupational and Public Safety

POL 1.2.3—Marine Transportation and Safety (MTS)
Canada's offshore areas are often under severe environmental conditions. The safe and efficient transportation of hydrocarbons by tankers not only requires an understanding of equipment, systems and operations, but also of how the tankers and their personnel are affected by these environmental conditions while in normal or emergency situations (such as escape, evacuation and rescue). The Marine Transportation and Safety (MTS) POL plan groups coordinated research initiatives from various federal departments that involve regulatory requirements relating to the safe and efficient transport of oil and gas by tankers and for related personnel safety needs. The research inputs into the fulfillment of governmental department mandates in support of energy development and sustainable development; provides the ability to make timely and economical engineering decisions and regulatory approvals and help to improve human safety and ensure environmentally safe oil and gas operations.

Some highlights within this POL include recorded data on detection distances of bergy bits; this resulted in the deployment of 5 Advanced Radar systems to key commercial and governmental clients. A draft of an operational guideline for escape, evacuation and rescue from offshore petroleum installations has also been completed; this will lead to a standard for use by industry and regulators. EC has contributed to the expansion of knowledge on the process of calving, drift, dispersion and deterioration of bergy bits. Critical data was taken in cold and moderate sea states as opposed to previous observations in warm and calm seas. Improved bergy bit size distribution parameterization was derived and the overall understanding of the melt of bergy bits has significantly improved.

An advisory group with non-vested interests provides a strategic overview of each activity and the POL as a whole, and determines the best mix of projects that can be done. Each project involves collaboration with various government departments such as NRCan, DFO, NRC, Transport Canada, regulators, CAPP, the oil and gas industry and various contractors and consultants.

The following activities are included under POL 1.2.3:

- Offshore Safety
- Marine Operations
- Ship Design

For 2001-2002 and 2002-2003, the POL plan included 8 individual projects of one- or two-year duration. In 2002-2003, POL 1.2.3 was in its first year of a four-year POL Plan. EC is leading 1 of these projects under the Marine Operations activity.

Profiles by Strategic Intent

Oil and Gas Sector

Regulatory Requirements for Occupational and Public Safety

The total 2001-2002 annual budget for POL 1.2.3 was $1,647,000, and $1,819,000 for 2002-2003. The total PERD resources available for 2001-2002 were $769,000 and for 2002-2003, $702,000. PERD funds were divided amongst the departments involved in this POL (see Table 3.). For this POL, the leverage quotient of total resources to PERD resources for 2001-2002 was 2.1 and 2.6 for 2002-2003.

Table 3. Percentage of PERD Funds for POL 1.2.3 Allocated to Each Department

Department	Percentage of Funds (%)	
	2001–2002	2002–2003
NRC	44.6	50.9
TC	21.3	23.1
NRCan	17.8	11.3
EC	10.1	11.3
Possibly POL Administration	6.1	3.6

Environment Canada Projects for POL 1.2.3

Prediction of Small Glacial Mass Distributions

Project Manager: Tom Carrières

Project Objectives
The project started in 2001-2002 and is an offshoot of the *Operational Ice Modelling* project in the OEF POL. *Prediction of Small Glacial Mass Distributions* looks into issues more related to energy transportation. It's main objective is to improve the safety of energy transportation (shuttle tankers) by developing better iceberg and bergy bit models and products.

This project benefits EC through its improved iceberg models and more accurate iceberg products.

Methodology
Field experiments are conducted to acquire information on bergy bit size distributions, drift, dispersion etc. Following data accumulation, there is an analysis of results. These results are then incorporated into models. Products are further developed and refined. Prototype products are then evaluated by industry.

Goals, Outputs and Project Success Story
Outputs of this project include an improved understanding of bergy bit characteristics, improved iceberg models and products as well as journal publications. This project has been able to collect highly valued information regarding bergy bits as well as new findings that have expanded world knowledge about the process of calving, drift, dispersion and deterioration of small glacial masses. For example, a significant number of new calving observations have been made in May 2002. This data is critical since it was taken in cold and moderate sea states as opposed to previous observations in warm and calm seas. An improved bergy bit size distribution parameterization has been derived and an overall understanding of the melt of bergy bits has improved.

Funding
The average resources allocated for this project per fiscal year were $250,000 (2001-2002; 2002-2003). An average 32% of these resources came from PERD funds, the rest came from other sources (A-Base, others such as IIP, industry). The average leverage quotient of total resources to PERD resources for the project was 3.1.

Profiles by Strategic Intent

Oil and Gas Sector

Regulatory Requirements for Occupational and Public Safety

Prediction of Small Glacial Mass Distributions

Strategic Intent 1 · Strategic Direction 3

Strategic Direction 3 is to provide S&T to address cross-cutting environmental and safety issues to support the production of Canada's onshore and offshore oil and gas resources.

Strategic Intent 1 · Strategic Direction 3 · Objective 1.3.1

The Regulation and Reduction of GHG and Other Atmospheric Emissions, Primarily from Flaring.

POL 1.3.1—Flaring Research Initiative

The oil and gas industry in Alberta now achieves a 92% conservation rate of the solution gas produced. The practice of flaring (combustion in a flare) disposes of the remaining portion that is not captured and marketed (over 1.8 billion cubic meters per year). There is considerable pressure on industry and government to reduce or eliminate flaring due to the public's concerns over potential environmental and health impacts. The practice of flaring is also a general concern since it has been identified as a significant contributor to greenhouse gas emissions. The Flaring Research Initiative (FRI) POL is a coordinated research initiative to reduce or eliminate the potentially harmful effects of flaring solution gas. Regulation of flares is presently under provincial jurisdiction. The federal government may become involved in future regulation of flares in the event that there is conclusive evidence of toxic emissions covered by the Canadian Environmental Protection Act. The study of flaring at all federal levels and industry must be pursued in order to reduce GHG emissions, to reduce potential health effects and to conserve a non-renewable resource.

The research under the Flare Performance Activity is potentially going to be used by the International Energy Agency to establish baseline greenhouse gas emissions worldwide from which any improvements in practice will be measured. The World Bank Global Gas Flaring Reduction Partnership (GGFR) is also promoting the adoption of many of the results of this initiative in the developing world where flaring of solution gas associated with primary oil production is widely practiced. A principal project completed during this reporting cycle was the technical assessment of an optical technology to determine the capacity to accurately monitor solution gas flare plumes for constituents such as methane (CH_4) and Sulphur Dioxide (SO_2) simultaneously under field conditions. This optical technology would be deployed during the final year of the POL 1.3.1 in order to monitor such things as flare combustion efficiency and pollutant dispersion within the flare plume. The research associated with this POL is critical in further advancing the development of flaring reduction technology and the development of science based flaring policy and regulation required to reduce or eliminate the impacts of flaring on the global environment.

The Flaring Research Initiative (FRI) groups a number of projects undertaken with the support of industry, CAPP, several federal departments such as NRCan, EC, NRC, provincial agencies such as, Alberta Energy and Utilities Board, BC Energy Mines & Resources, Alberta Energy Research Institute and the Alberta Department of Energy.

The following activities are included under POL 1.3.1:

- Flare Performance
- Speciation
- Liquid Separation
- Fate and Transport

EC participates in all the projects within this POL via EC's Bill Reynen who is an active member of the PTAC Technical Steering Committee for POL 1.3.1

The total 2001-2002 annual budget for POL 1.3.1 was $3,726,000, and $919,000 for 2002-2003. The total PERD resources available for 2001-2002 were $530,000 and for 2002-2003, $599,000. For this POL, the leverage quotient of total resources to PERD resources for 2001-2002 was 7, and 1.5 for 2002-2003.

Table 4. Percentage of PERD Funds for POL 1.3.1 Allocated to Each Department

Department	Percentage of Funds (%)	
	2001–2002	2002–2003
EC	100	100

Strategic Intent 1 · Strategic Direction 3 · Objective 1.3.3

The Remediation of Groundwater and Soil Issues.

POL 1.3.3—Soil and Groundwater Remediation

Oil and gas production impacts on groundwater and soils. The Soil and Groundwater Remediation POL was designed to increase the knowledge base on contaminant transport and transformation in soil and groundwater, and determine the degree to which flora and microbial communities can contribute to hydrocarbon degradation. Activities of POL 1.3.3 aim to develop more economic, effective, efficient, and environmentally innocuous remediation technologies with the goal of making them more appealing to site owners than conventional methods. The POL also aims to contribute to the development of standards and regulations for acceptable levels of residual hydrocarbons in soils and groundwater.

Some highlights within this POL include the PERD sponsored project by EC "Standardization and validation of terrestrial toxicity test procedures for assessing biological effects in hydrocarbon contaminated soils". This project will standardize new terrestrial soil toxicity test procedures using species relevant to the Canadian soil systems and field validate the toxicity tests using contaminated soils from facilities that produce natural gas and other alternative hydrocarbon-based fuels. This work directly supports some important programs at EC such as CEPA's Code of Good Environmental Practice for Industrial Site Decommissioning. Building on earlier PERD research that showed that boreal wetlands were capable of naturally fixing and removing hydrocarbon contaminants, EC scientists are studying the ability of wetlands to provide a cost-effective treatment for the waste effluents of gas plants. The project will evaluate the fate of the waste products and their effects on wetlands. Preliminary results from these studies suggest it might be more beneficial to simply monitor and stimulate natural processes. The increased knowledge will also advance the ability of EC to effectively develop its codes of practice and guidelines for the protection of wetlands. Gas-plant site-management strategies have been refined based on evidence of abatement of the plumes where there are natural wetlands on sites. Industry is no longer excavating natural wetlands. Another project entitled "Biological barriers in fractured bedrock" is investigating natural attenuation processes that will limit migration and break down toxic compounds. Through this new process, injection of a carbon source into the contaminated media stimulates the multiplication of indigenous ground water bacteria. In turn, these bacteria form a biobarrier to the movement of toxic compounds. Essentially, the permeability of the media is decreased as the enlarged bacteria concentration ingests and bio-transforms the contaminants. The project is ongoing and the biosafety aspects are yet to be fully evaluated, but it has drawn interest from a wide group of interested parties, and shows a remarkable potential as another tool in the broadening sphere of green technology that strives toward zero impact solutions.

The POL has increased its involvement and partnership with industry and industry groups, such as the Petroleum Technology Alliance of Canada (PTAC) and the Canadian Petroleum Producers of Canada (CAPP) and other industry and university research partners (such as Utah State University, University of North Dakota, l'École Polytechnique de Montréal, and many more). Participating departments include NRCan, NRC, and EC.

The following activities are included under POL 1.3.3:

- Modeling and Monitoring of the Fate and Behaviour of Hydrocarbons in Anaerobic Environments
- Development of Remediation Technologies for Hydrocarbon Contamination in Groundwater and Soil
- Regulatory Development- Supporting Data to Advance the Development of Guidelines and/or Standardized Tests for Regulatory Development.

The POL has maintained international partnerships such as the work done in collaboration with UFZ Germany in support of a Doctoral dissertation research on a toxicity based approach to measure the effectiveness of attenuation mechanisms for the removal of toxic naphthenic acids and precursors in contaminated water and soil samples. The POL has also maintained collaboration with the Energy and Environmental Research Centre at the University of North Dakota and USDOE. The Groundwater Research Program has allowed the POL to contribute internationally in this area.

For 2001-2002, the POL plan included 13 individual projects. For 2002-2003, 14 individual projects were in progress. In 2002-2003, POL 1.3.3 was in its third year of a four-year POL Plan. EC is leading 13 of these projects.

The total 2001-2002 annual budget for POL 1.3.3 was $3,229,800, and $4,279,000 for 2002-2003. The total PERD resources available for 2001-2002 were $891,500 and for 2002-2003, $860,000. PERD funds were divided amongst the departments involved in this POL (see Table 5.). For this POL, the leverage quotient of total resources to PERD resources for 2001-2002 was 3.6 and 5.0 for 2002-2003.

Table 5. Percentage of PERD Funds for POL 1.3.3 Allocated to Each Department

Department	Percentage of Funds (%)	
	2001–2002	2002–2003
EC	80.9	91.3
NRCan/EC	19.1	8.7

Environment Canada Projects for POL 1.3.3

Natural Wetlands - Containment, Transformation and Remediation of Toxic Organics from Natural Gas Condensates and Process Chemicals

Project Manager: John Headley

Project Objectives

This project is a continuation of a previous PERD project on the development of the analytical/toxicity methods for gas plant sludges and contaminated groundwater.

The objectives of this work are to:

- Extend the analytical/toxicity methods developed for gas plant sludges and contaminated groundwater to determine the effectiveness of natural wetlands in attenuating toxic contaminants and their transformation products in gas condensates;
- Evaluate the effects of hydrocarbon impacts on wetlands ecosystems;
- Develop a model to describe the behaviour of natural gas condensate and process chemicals in wetlands for general management and treatment of waste at gas plants.

The research provides science and technology to address crosscutting environmental and safety issues to support the production of Canada's onshore oil and gas resources. More specifically, this project addresses Objective 1.3.3 "The remediation of groundwater and soil issues programs" pertaining to sustainable energy sources and containment of toxic substances in the environment in support of Environment Canada's commitment to: (a) sustaining renewable energy resources and (b) developing codes of practice and guidelines for the environmental protection of wetlands. The results directly support the department in filling knowledge gaps on priority substances in the environment, (particularly amines, aquatic ammonia, and PAHs), and expedites the development of guidelines and regulatory standards for these substances.

Methodology

There is substantial evidence that natural wetland systems exposed to gas-condensate and process chemicals have a natural ability to assimilate and in some cases degrade contaminants. New evidence is emerging that DIPA is uptaken primarily in the root zone while sulfolane can translocate to upper portions of cattails (*Typha latifolia*) at wetland sites investigated. For this fiscal year, work has focused on (a) preparation of a report on plant uptake of DIPA and sulfolane in cattails grown in laboratory growth chambers; and (b) initiating experiments to determine the fate and transformation of DIPA and sulfolane in decayed wetlands plants.

In support of the growth chamber studies, it was necessary to refine the analytical methods for the determination of various alkanolamines. An ion exchange electrospray ionization MRM method was used to determine the levels and spatial distribution of DIPA in Typha latifolia. Cattails were grown hydroponically in aqueous solutions containing known concentrations of DIPA for a period of 50 days. At the same time non-exposed cattails were grown and non-planted hydroponic solutions and were run simultaneously as controls. Approximately 1 gram of homogenized plant tissue from various regions of the plants (leaves and roots) was extracted followed by the addition of an internal standard. Ion exchange chromatography was used for the analysis. Reaction monitoring, using argon as the collision gas, was chosen as the method for quantification. The method provided increased selectivity for all analytes and better sensitivity for 3 of the 6 analytes investigated. Instrumental detection limits ranged from 6 - 300 pg injected for monoethanolamine (MEA), monoisopropanolamine (MIPA), diethanolamine (DEA), methyldiethanolamine (MDEA), diisopropanolamine (DIPA), and triethanolamine (TEA). Method robustness and selectivity was demonstrated by the determination of DIPA and a known transformation product MIPA in over 35 plant extract samples. Results indicate that spatial distribution of DIPA concentrations were highest in the root section with an average of 3.5 times the amount as compared to that of the upper foliar tissues (leaves or shoots).

Goals, Outputs and Project Success Story

A key step will be to further focus the research on quantifying the uptake of natural wetland plants in the overall attenuation and transformation of process chemicals and gas-condensate hydrocarbons. Likewise, it is necessary to quantify the risk posed to wildlife feeding on the wetlands plants accounting for variables such as: field heterogeneity in the plants, variability in groundwater concentrations and possible bioconcentration in plants. Specifically, the observation of significant uptake of sulfolane by cattails implies that sulfolane contaminated wetland plants may present a potential ecological risk to wetland animals that consume these plants. There is thus a need to more fully address the following data gaps: What is the fate of sulfolane in plant material after the plant die? Is the material recycled within the wetlands? How long does it persist? What are the highest concentrations that could accumulate in plants? Does the sulfolane taken up in plants get passed along through the food chain to other organisms? What are the impacts of environmental variables (ie temperature, water quality, plant species, etc.) on the uptake and accumulation of sulfolane in plants? Filling these knowledge gaps is a prerequisite for completion of a conceptual model describing the overall attenuation of contaminants in natural wetlands.

Outputs for the project are:

- Standard protocol development based on a T.I.E. approach for the quantification of the degree of attenuation of principal toxic which are transformed or remediated in natural wetlands at participating gas plants. Work in collaboration with partners (Deib Birkholz, Envirotest Labs, Steve Goudey, Hydroqual Labs, Karsten Liber, Toxicology Research Group, Jon Gillies, U of S) is progressing well as evidenced by the external peer reviewed papers, published on standard procedures developed for the determination of process chemicals in wetland vegetation.

- Evaluation of attenuation processes to assess the fate and transport of contaminants in natural wetlands at participating gas plants. Collaborative work has continued with partners (University of Utah; Duane Friesen, Malispina University College) and is progressing well as evidenced by external peer reviewed papers, technology transfer at workshops and invited seminars. As part of technology transfer to the oil-and-gas industry, the results obtained for this output were also presented at the PTAC/CAPP Technical Forum, Calgary, Alberta, May 14-16, 2003.

Generation of a model describing the transformation and remediation of toxic contaminants based on measurements of attenuation of principal toxic components in natural wetlands at participating gas plants. As per the Performance Measurement Framework, emphasis

Profiles by Strategic Intent

Oil and Gas Sector

Remediation, Groundwater and Soil Issues

Natural Wetlands - Containment, Transformation Remediation of Toxic Organics

- has been placed on data collection and evaluation. Research is continuing in collaboration with Bill Doucette, Utah State University, to fill key knowledge gaps on risk assessment and quantifying the role of plants in the overall attenuation. Results will be used for the development of the model required for the 3rd output as scheduled. Activity for the latter will be the focus of activity in 2004-06, the wrap up phase of the Project.

NWRI Lead on Energy Research Issues in Western Canada

As a direct result of the expertise acquired in the Project, the Study Leader served as the NWRI Lead on Energy Research Issues in Western Canada; and as External Reviewer for the "Soil and Water Quality Guidelines for sulfolane and diisopropanolamine: environmental and human health" on behalf of CCME. The results of the PERD wetland project are featured in both guidelines, in which there is discussion of the levels of the process chemicals in the Canadian environment near gas plants.

Influence on industry's practices: Gas-plant site-management strategies have been refined based on evidence of abatement of the plumes where there are natural wetlands on sites. Industry is no longer excavating natural wetlands, which is a direct influence and impact of the research results from the POL's Wetlands project.

Funding

The average resources allocated for this project per fiscal year were $276,000 (2001-2002; 2002-2003). An average 25.4% of these resources came from PERD funds, the rest came from other sources (A-Base, industry (Oil & Gas Sponsors Watersearch Corp.), and other such as U of Alberta, U. of Saskatchewan, Utah State University). The average leverage quotient of total resources to PERD resources for the project was 3.9.

Remediation of Naphthenic Acids in Subsurface Soils and Groundwater at Oil Extraction Plants

Project Manager: John Headley

Project Objectives
This project is a continuation of the on-going PERD project on *Remediation of Naphthenic Acids in Subsurface Soils and Groundwater at Oil Extraction Plants*

The key objective is to determine the factors controlling the fate and transport of toxic naphthenic acids to soil and groundwater at oil production facilities. In turn, it is anticipated that the results will:

- Form a basis for technology development for improvement of the attenuation of these substances in the subsurface;
- Facilitate microbial degradation in near-surface and aquifer biofilms and;
- Improve our understanding of their reduction in oxygen-limited environments.

The Project provides expertise to PERD in support of Environment Canada's commitment to: (a) sustaining renewable energy resources and (b) developing guidelines and cost-effective methods for remediation of naphthenic acids, in tailings reclamation soils and sediments.

Methodology
Naphthenic acids (NAs) are some of the most toxic poly-cycloalkane carboxylic compounds present in oil sand tailing wastes. During the bitumen extraction process, 1 m^3 of mined oil sands requires 3 m^3 of water, and produces on average 4 m^3 of waste. The tailings slurry wastes are contained in large settling ponds. Syncrude Canada Ltd., the largest single producer of synthetic oil from the oil sands, has in excess of 300 million m^3 of tailings contained in these ponds. It is assumed that there is little or no escape of contained tailings from the basin of ponds to the subsurface.

There are however, major knowledge gaps pertaining to the degradation and removal of toxic naphthenic acids in subsurface environments associated with oil extraction. It is known that complex mixtures of naphthenic acids are pre-disposed to leach to subsurface soils and groundwater and that this transport is mobilized by their high water solubility. This project integrates studies to accelerate the development of an effective and efficient bioremediation process of NAs through:

- The refinement of analytical methods and study of the biodegradation of NAs;
- Gaining insights from understanding the mechanism and transformation of metabolites as microorganisms are exposed to NAs and;
- The development of suitable endpoints to drive bioremediation strategies.

Goals, Outputs and Project Success Story
Outputs for the project include:
Refinement of analytical methods for quantification of NAs components to determine their bioavailability in oil sand sediments and reclaimed soils. Steady progress has been made to date as evidenced by the development of initial analytical methods. Research has been initiated to apply recent advances in high field mass spectrometry and 2-D gas chromatography to more fully characterize the complex naphthenic acid mixtures.

Profiles by Strategic Intent

Oil and Gas Sector

Remediation, Groundwater and Soil Issues

Naphthenic Acids in Subsurface Soils and Groundwater

- Development of Toxicity Identification and Evaluation (TIE) procedure for fractionation and isolation of oil sands NAs toxic compounds in oil sands sediments and reclamation soils. The TIE collaborative work has commenced in support of a PhD thesis program at the University of Guelph. A specialist in sediment toxicology and TIE will be added to the research team (NWRI) as per the recommendation from the PERD Advisory committee.
- Remediation method for toxic NA compounds in contaminated soils and oil sands tailings. A toxicity based approach to measure the effectiveness of attenuation mechanisms (biodegradation and photodegradation) for removal of toxic naphthenic acids and precursors in contaminated soils and water samples is in progress in collaboration with Dena McMartin, U of S, and Karsten Liber, Toxicology Research Group. The preliminary phase of this work was completed December 2003. Parts of this work were performed in collaboration with UFZ, Germany by Dena McMartin, in support of a PhD thesis research in environmental engineering.

Work is continuing in collaboration with Profs. S.L. Barbour, Jon Gillies and Dr. J-L Du, Environmental Engineering Division, U of S to perform laboratory experiments on the persistence of complex naphthenic acid mixtures. Laboratory analyses for this work has been performed by Dr. John Headley at NWRI (Saskatoon) in co-operation with the U of Saskatchewan. As part of new initiative, studies were conducted in partnership with Dr. Hans Peterson to determine the role of phytoremediation as a treatment option for removal of naphthenic acids in contaminated soils/groundwater. The latter was supported in part by the Horizon Youth Program.

As a result of technology transfer arising directly from this project, new partners have joined the research team with funding leveraged from industrial sponsors. The U of R will collaborate on the remediation of naphthenic acid contaminated soils and water; while the MOE and U of Warwick will help develop new analytical tools employing 2-dimensional gas chromatography mass spectrometry and high field accurate mass spectrometry respectively, for the determination of the principal toxic naphthenic acids in aquatic environments.
The work this fiscal year has focused on establishing the role of aquatic algae as a treatment option for removal of naphthenic acids in contaminated soils/groundwater. Initial results indicate that algae are capable of inducing composition changes and reduction in concentration of various naphthenic acid mixtures. Research is continuing to expand on preliminary findings to measure the overall reduction in aquatic toxicity associated with the degradation of the naphthenic acids and to elucidate the dependence of changes in toxicity with the structure of the respective naphthenic acid components. The latter is being conducted in collaboration with Dr. Karsten Liber, Toxicology Group, University of Saskatchewan.

As a direct result of expertise acquired in this project, the Study Leader has been invited by the Editorial Board of the Journal of Chromatography to prepare a 3 part- series of papers on naphthenic acids for a special issue, to be published during the summer of 2004.

Funding

The average resources allocated for this project per fiscal year were $154,500 (2001-2002; 2002-2003). An average 32.0% of these resources came from PERD funds, the rest came from other sources (A-Base, industry, others such as U. of Saskatchewan). The average leverage quotient of total resources to PERD resources for the project was 3.1.

Groundwater Research Program (USDOE)

Project Manager: Bill Reynen

Project Objectives

The main objective of this project is to examine the transport and fate of waste streams generated by natural gas processing operations.

This project stems from GRI/DOE Gas Industry Groundwater Program research started in 1996 which focused its efforts on studying waste streams generated by natural gas processing operations. In particular, the program conducted laboratory-based research activities designed to generate fundamental data regarding the chemical nature, and subsurface transport and fate of alkanolamines (used for gas sweetening), glycols (used for gas dehydration), and their associated wastes.

With respect to the POL's involvement, this project studies condensate mobility in soil. The focus on Natural gas condensates and glycol characterization and interaction between chemical, soil, and water as well as natural attenuation.

This project benefits EC since it increases the knowledge base on contaminant transport and transformation in soil and groundwater.

Methodology

Research activities that can be grouped into the following four areas:

- Field-based investigations of subsurface contamination associated with glycol-based natural gas dehydration systems and alkanolamine-based gas sweetening units;
- Laboratory-based investigations of the cosolvent effects of glycols on selected condensate species in a variety of North American soils;
- Laboratory- based evaluations of the biodegradability of glycol-based dehydration wastes, and;
- Computer modeling of subsurface transport and fate of gas-sweetening and dehydration wastes using data generated in the laboratory and the field.

Goals, Outputs and Project Success Story

This project has allowed the POL to contribute internationally in this area. Collaboration with our US counterparts has provided significant leveraging of research resources and funds in this area.

In 2002, column experiments were conducted, biodegradation experiments were completed and lab and field results will be verified and validated with known glycol and condensate contamination.

The EERC was on site at a natural gas processing plant located near Lesser Slave Lake, Alberta, Canada, on June 11th and 12th, 2002 to collect sediment and groundwater samples for BTEX, glycol and microbial analysis. Additional groundwater samples were collected by Matrix Solutions in October, 2002. Data collected is to be used in predictive transport & fate and/or risk-based corrective action (RBCA) and environmentally acceptable endpoint (EAE) models. Models will be expanded for application to the oil & gas industry in Canada.

Funding

The average resources allocated for this project per fiscal year were $1,601,500 (2001-2002; 2002-2003). An average 3.1% of these resources came from PERD funds, the rest came from other sources (GRI, USDOE). The average leverage quotient of total resources to PERD resources for the project was 32.4.

The Role of Sulfate Reduction in the Bioremediation Technologies for Hydrocarbon Contamination in Groundwater

Project Manager: Dale Van Stempvoort

Project Objectives

This project is coordinated in cooperation with a larger study of monitored natural attenuation, which is being conducted by CORONA (Consortium for Research on Natural Attenuation), lead by University of Alberta and Komex International Ltd. For example, parallel investigations at one site includes sharing of information and mobilization costs. The main objectives of this projects are:

- To investigate the role of sulfate reduction in the natural attenuation of hydrocarbon contaminants in groundwater in Canada under oxygen-limited, low temperature conditions.
- To investigate ways to enhance/stimulate this anaerobic biodegradation process.

This work addresses a main priority area in the PERD groundwater and Soil Remediation POL: Fate, transport, biodegradation and natural attenuation.
This study contributes to the EC Clean Environment Business Line, and more specifically towards the following Results: The environmental and human health threats posed by toxic substances and other substances of concern are prevented or reduced.

Methodology

The field component of the study has included drilling, and sampling of soil and/or groundwater at 3 sites in Alberta, injection of sulfate solutions into wells at 2 of the sites. Chemical analyses of soil and groundwater included a focus on sulfur compounds and hydrocarbons, including stable isotope analyses. Laboratory investigations include microcosm tests with groundwater samples. To determine which microorganisms were abundant/important in hydrocarbon-contaminated zones, DNA was extracted from field and microcosm sediment samples. In 2004/05, drilling at one site will complete the database required for numerical simulation of the plume biodegradation processes. Additional microcosm tests will address remaining knowledge gaps: iron sulfide as a key sink of sulfide produced by sulfate reduction, and whether benzene is biodegraded under sulfate reducing conditions in groundwater at the site.

Goals, Outputs and Project Success Story

The anticipated outputs of this project are:

- Improved/validated input data for existing models or new predictive models characterizing the fate and behaviour of hydrocarbons in anaerobic environments.
- Potentially a new technology to enhance remediation of hydrocarbons in groundwater via sulfate reduction.

In 2004/05, comprehensive evaluation of field and laboratory data will include numerical modeling. Reporting will include final report to PERD, and several journal publications.

In 2002/03 and 2003/04, this study showed that sulfate reduction is a key, dominant electron accepting process in hydrocarbon plumes in groundwater at 3 sites in Alberta. The injection tests indicated potential to add sulfate to groundwater as an enhanced in-situ bioremediation technique, and provided key data on in-situ sulfate reduction rates. Initial microbial detections included sulfate and metal-reducing bacteria.

Funding

The average resources allocated for this project per fiscal year were $195,000 (2002-2003 only). An average 41.0% of these resources came from PERD funds, the rest came from other sources (A-Base, industry (LAOGMT, Conoco, Komex Intl) and others such as NWRI, U. of Calgary, CORONA). The average leverage quotient of total resources to PERD resources for the project was 2.4.

Remediation of Hydrocarbon-Contaminated Sites by Monitored Natural Attenuation (MNA)

Project Manager: Bill Reynen

Project Objectives

The major objective of this study is to better understand how attenuation processes work in different situations to better predict the most suitable areas that lend themselves to this approach in a timely fashion. It could offer an economical alternative to more aggressive interventions. The monitoring aspect of this approach is important to confirm that natural attenuation processes are indeed working, and that contaminant plumes are not threatening nearby landowners or sensitive ecosystems.

Methodology

The second phase of this project, started in 2001, involving detailed assessments at three sites to demonstrate that natural attenuation is occurring. This process includes detailed site characterization, sampling, and biodegradation testing and groundwater monitoring which resulted in the selection of three sites for further studies.

In 2002-03 detailed site characterization was continued at all three research sites. The program focused on well installation for sample collection methodology testing and monitoring variability assessment. Work continued to focus on how sample collection might affect the interpretation of natural attenuation behavior.

Seasonal monitoring was continued (quarterly sampling) to assess possible seasonal influences on data used to support natural attenuation. Groundwater monitoring was conducted on a quarterly basis. Seasonal monitoring was continued (quarterly sampling) to assess possible seasonal influences on data used to support natural attenuation. Groundwater monitoring was conducted on a quarterly basis.

A program was started at University of Alberta to assess how well diffusion-based sampling systems could be used for groundwater monitoring. The ongoing program has involved laboratory trials and one field application.

Technical Steering Committee has been created to work with Alberta Environment to develop recommendations and content of a "Guideline for the Use of Monitored Natural Attenuation at Contaminated Sites in Alberta". The primary focus was to outline a proposed administrative and technical framework for managing contamination at only upstream oil and gas sites such as wellheads or compressor stations. However, the Guideline will also allow for a "generic" evaluation of the applicability of MNA to other contaminated sites or risk management issues. Due to unforeseen difficulties at AENV, the work on the Guidelines was halted. The Committee resumed its work in early 2003. The MNA Guideline document is to be released in 2004.

The purpose of the Guideline is to fit into the framework of several AENV initiatives including the Policy for Management of Risks at Contaminated Sites in Alberta and the 2001 Geo-Environmental Assessment & Remediation of Petroleum Hydrocarbons in Alberta.

Goals, Outputs and Project Success Story

The Monitored Natural Attenuation project is on track and is working towards demonstrating environmentally acceptable endpoints by natural attenuation. Modeling data to characterize the fate and behaviour of hydrocarbons in aerobic environments is being gathered and compiled. Field trials of BART™ kits are progressing while work is underway to modify and improve the site characterization tools.

Funding

The average resources allocated for this project per fiscal year were $212,000 (2001-2002; 2002-2003). An average 16.5% of these resources came from PERD funds, the rest came from other sources (Industry (CAPP, Conoco, Devon, Komex) and others such as COURSE, NSERC). The average leverage quotient of total resources to PERD resources for the project was 6.1.

Assessment of Phytoremediation as an In-Situ Technique for Cleaning Oil Contaminated Sites.

Project Managers: Dr. Terry McIntyre (In collaboration with Dr. Jim Germida-University of Saskatchewan, Dr. Xiamon Lei-Alberta Research Council, Drs. Peter Kulaiko / Steven Rock / USEPA

Project Objectives

This project is a continuation of a smaller PERD project launched with funds levered from the Canadian Biotechnology Strategy in 2001-2002.
This project was intended to explore the utility of plant based remediation of sites impacted by total petroleum hydrocarbons and under presented prairie ecozone conditions (and as an adjunct to an ongoing US EPA remediation technology demonstration forum involving 11 other sites across United States and Alaska-all utilizing the same protocols.

This research provides PERD PTAC with a database of plants found to tolerate and remediate TPH's in Prairie Ecozones, protocols on how to employ plants for these purposes, access to comparable ecozone sites from across US, and a basis for site owners and managers alike to utilize *in situ* , solar driven, low cost plant based remediation and restoration tools.

Where appropriate, EC and other scientists with an interest in phytoremediation can now extrapolate from Prairie ecozone conditions and explore basic research on how plants could be used at comparable petroleum impacted sites across Canada. EC has also benefited from considerable empirical data from the University of Saskatchewan and Alberta Research Council scientists to help better clarify / resolve regulatory, scientific, technical, policy, biosafety, and biodiversity issues likely to be raised by large scale.

Methodology

There have so far been 55 species identified as potential phytoremediator plants, able to survive western Canadian climatic conditions. These include 38 native species and 17 introduced species. Based on preliminary screening in clean and contaminated soils, the number of candidate plants was reduced to 11 cold-tolerant perennials. Preliminary analysis demonstrates that varying levels of microbial populations occur between the subplots, reflecting the effects of spatial variability of contaminant concentration. Molecular and culture techniques indicated that the populations of total heterotrophic bacteria and hydrocarbon-degrading bacteria varied from soil to soil depending on contaminant levels. Similar differences were noted for communities associated with roots of different plants growing in contaminated soils. Soils collected from the field sites are being used for further studies and to help select species to be included in the local plant mix at the two sites. These studies will continue for at least three years.

Goals, Outputs and Project Success Story

- A report has been prepared on the feasibility of the technology as well as the plant species suitable for this application.

An inventory of candidate plant species has been developed that could be employed for remediation and restoration of sites contaminated with TPH's

- in Western Provinces (currently being translated into French and available June 2003).
- Data have been generated on the potential for using compost as a carrier for hydrocarbon degrading bacteria.
- An improved understanding has been attained of the root exudate production of native plants utilized or that could be utilized in PHC remediation.
- Research is constantly improving on the evaluation of the effectiveness of phytoremediation in reducing hydrocarbon (TPH and BTEX) concentrations in soils contaminated with historical or weathered compounds.
- A protocol has been completed for the fractionating of different compound classes from aqueous extract of the root exudates and concentrating and derivatizing them for GC analysis.

Funding

The average resources allocated for this project per fiscal year were $240,000 (2002-2003 only). An average 47.9% of these resources came from PERD funds, the rest came from other sources (A-Base, industry (PTAC, Federal Pioneer) and others such as NSERC, Saskatchewan Environment, USEPA). The average leverage quotient of total resources to PERD resources for the project was 2.1.

Biological Barriers in Fractured Bedrock

Project Manager: Nathalie Ross and Suzanne Lesage

Project Objectives

This project was initiated following work conducted at *Ecole Polytechnique de Montréal* between 1994 and 1999. It led to a second PERD project: "Attenuation of an Ethanol/BTEX Plume in Fractured Bedrock Model Undergoing Biostimulation.". The collaboration between NWRI and Queen's University, on developing the biobarrier concept at field scale and modeling the effects of a biofilm in a fractured media, is planned to continue with the participation of industrial partners.

The development of a biobarrier in a fractured rock aquifer increased the scientific knowledge for an integrated groundwater management framework. This biobarrier concept represents an innovative method to improve bioremediation and to allow other natural attenuation processes to occur. The laboratory experiments allowed to analyze the change in microbial diversity, to measure ecotoxicological responses, and to observe the development of the biofilm in a single fracture.

The project's main objective was aimed at reducing permeability and preventing migration of contaminants in a fractured media, by injecting a carbon source to stimulate the groundwater bacteria. The specific objectives of the project are related to hydrogeological and physicochemical aspects, and environmental biosafety:

- to design an installation consisting of a well for the delivery of nutrients and a network of monitoring wells to evaluate the formation of the biobarrier;
- to monitor the changes in physicochemical conditions due to the bioclogging;
- to evaluate the effects of the biostimulation on the ecosystem, especially with respect to ecotoxicity and microbial diversity.

This project benefits EC by addressing the mandate on "Clean Environment". It contributes to the NWRI's role by generating and disseminating scientific knowledge needed to resolve environmental issues of regional, national, or international significance to Canada. The biotechnological aspects might benefit the New Substances Program specifically in providing data for the New Substances Notification Regulations.

Methodology

The following methodology refers to outputs 1 through 4.

- Output 1: Under constant groundwater flow and carbon source injection, the bioclogging of single fracture models was monitored by measuring biofilm development and analyzing effluent components. The possibility of using the biobarrier technique as a containment barrier (significant reduction of permeability) and/or reactive wall (significant reduction of contaminant concentration) will be determined.

- Output 2: The assessment of the biosafety of biostimulating indigenous bacteria was conducted at laboratory scale and field scale. A glass-fracture table was used to determine the most relevant monitoring tools for the field (Mississauga, Ontario). In

- addition, a battery of biomolecular analyses and biotests were used to monitor microbial changes and ecotoxicological responses at Mississauga site.

- Output 3: The field trial, conducted in a horizontal fracture in limestone shale was planned to determine: 1- technical feasibility of the biobarrier concept, 2- design parameters for a full size field scale, and 3- how "green" the concept is. The duration of the work was 3 years; the first year being used for field setup (ex. drilling of new boreholes, pumping tests, etc.). The experiment consisted of supplying carbon source and measuring the extent of bioclogging. One major concern was to evaluate the longevity of the biobarrier. The aspect of longevity is crucial for the acceptability of this "green" technology.

- Output 4: The modeling was part of laboratory experiments as well as the field trial. Mathematical models were developed specifically for bacterial transport and biofilm development in fractured media. Fractured rocks remain an unexplored media for modeling bacterial development.

Goals, Outputs and Project Success Story

Outputs for this project include:

- Output 1: Knowledge on the possibility of enhancing natural attenuation using natural adjuvants;

- Output 2: Evaluation of the bacterial community and the ecotoxicology of the method using biomolecular techniques (this partially addresses the environmental endpoint priority);

- Output 3: Field trial of an innovative "green" technology of containment;

- Output 4: Experimental results supported by modeling.

Highlights of this new process in bioremediation include the following:

- The field trial showed a reduction in hydraulic conductivity by as much as 4 to 5 orders of magnitude. The stability of the biobarrier was tested under starvation conditions. After more than 8 weeks of monitoring, results show no change in the bioclogging. To our knowledge, this demonstration is the first attempt to develop a biobarrier in a fractured rock environment.

- Laboratory observations, field results, and modeling activities confirmed that the decline in groundwater velocity was positively correlated to the biofilm development; a vital requirement for a field demonstration of the biobarrier concept.

- The field-scale assessment corroborated that flow through conditions do not bring ecotoxicity although bacterial activities generate soluble microbial products.

- The results from the biofilm experiments have been used to validate this model and to assign average mass transport parameters to the biofilm.

Funding

The average resources allocated for this project per fiscal year were $370,000 (2001-2002; 2002-2003). An average 21.6% of these resources came from PERD funds, the rest came from other sources (A-Base, industry (Petro Canada) and others such as l'École Polytechnique). The average leverage quotient of total resources to PERD resources for the project was 4.6.

Profiles by Strategic Intent

Oil and Gas Sector

Remediation, Groundwater and Soil Issues

Biological Barriers in Fractured Bedrock

Solar Detoxification of Groundwater

Project Manager: Carl Brown

Project Objectives

This is a new project in the current POL plan. "Solar Detoxification of Groundwater" provides new technology (solar energy based) for the remediation of groundwater contaminated with petroleum hydrocarbons.

This innovative remediation technology benefits EC in several ways. It could treat substances on the CEPA Toxic and Priority Substance List. In addition, the solar detoxification process offers the potential for significant energy savings in the treatment of groundwater. This new technology may contribute to the reduction of the environmental footprint and at the same time demonstrate an innovative approach in alternate energy source application.

Methodology

Organic contaminants such as benzene, toluene, ethylbenzene and xylene (BTEX) represent a common problem found in industry. A number of technologies have been developed and demonstrated for the treatment of contaminated groundwater. These technologies include advanced oxidation process (AOP), steam stripping, air stripping and monitored natural attenuation. Each technology has its own set of advantages and limitations.
Recently a solar-based AOP technology was developed by a group of Canadian researchers. A range of organic compounds, for example, BTEX, NDMA, vinyl chloride, trichloroethylene, dichloromethane, dichloroethane and, trichloroethane could be treated by this technology.

Conventional AOP typically uses ultraviolet (UV) light and an oxidant (H_2O_2 or ozone) for the degradation of organic compounds in water. The UV light causes photolysis of the oxidant which creates hydroxyl radicals. These hydroxyl radicals, being highly reactive, will then breakdown the organic compounds in water. The use of UV light is the most effective radiation source for this process because the oxidant absorbs radiation most efficiently in the UV range of 200-300 nm. However, the UV lamps can be expensive to purchase and maintain. Solar energy would appear to be a viable alternative but very little solar spectrum falls in the UV range due to atmospheric absorption.
Since hydrogen peroxide and ozone do not absorb significantly beyond 300 nm the solar source is not suitable for these absorbers. An alternative for this is the injection of ferrioxalate that absorbs in the region of 250-480 nm (Bolton & Cater, 1996). Photolysis of ferrioxlate generates iron(II) which then reacts with hydrogen peroxide to produce hydroxyl radical. As in conventional AOP, hydroxyl radicals then degrade organic contaminants in the treated medium. As hydroxyl radicals are generated, iron (II) is oxidized to iron(III). Iron (III) chelates and acts as a catalyst to continue the generation of iron (II) under irradiation. Previous research had demonstrated that photolysis of the ferrioxalate in the presence of hydrogen peroxide provides a continuous source of radicals. When conditions are correct, iron (III) chelates act as a catalyst in this process.

Goals, Outputs and Project Success Story

Bench-scale test completed with excellent contaminant destruction results.
Field-scale equipment designed, assembled and tested.

Field-scale system tested and demonstrated excellent contaminant destruction results. Performance prediction model developed.

Currently, a technology deployment design guide is being developed. A system performance prediction model is being linked to available local weather data. A brief technology assessment is being conducted to identify potential areas for technology implementation.

Research was conducted to develop this technology further through bench-scale and field-scale work. Bench-scale test results showed excellent destruction of BTEX, MTBE and MMT contaminants. This is consistent with our earlier experience in BTEX and MTBE destruction using conventional AOP systems. A site was selected in British Columbia to conduct the field demonstration. A suitable field scale system was procured and assembled. Test equipment operated well in the field and system components performance met expectations.

Funding

The average resources allocated for this project per fiscal year were $112,500 (2001-2002; 2002-2003). An average 55.6% of these resources came from PERD funds, the rest came from other sources (A-Base, industry). The average leverage quotient of total resources to PERD resources for the project was 1.8.

Profiles by Strategic Intent

Oil and Gas Sector

Remediation, Groundwater and Soil Issues

In-Situ Soil Flushing

In-Situ Soil Flushing for the Remediation of Hydrocarbon Contaminated Soil

Project Manager: Carl Brown

Project Objectives

The primary objective of this project is to develop an enhanced *in-situ* soil flushing process for the simultaneous removal of organic contaminants and heavy metals. Sites with mixed contamination represent a significant number of contaminated sites and are often associated with fuel processing (refineries) and power generation (thermal power plants) activities. *In-situ* flushing involves the removal of contaminants from soil, sediment or groundwater by pumping water or chemicals (cleaning solution) into the contaminated area through injection wells. The process works *in-situ*, which means that the polluted soil is cleaned up in place and does not need to be excavated.

This project benefits EC since it aims to develop a more economic, effective, efficient, and environmentally innocuous remediation technology. As cleaning medium it uses a water-soluble derivate from by-products of pulp and paper industry, thus reusing a potential polluting product to clean contaminants from soil. This technology treats substances on the CEPA Toxic and Priority Substance List. This new technology may also contribute to the reduction of the environmental footprint and at the same time demonstrate an innovative approach in alternate energy source application.

Methodology

In this project, the active components of the cleaning solution are water-soluble derivatives of natural biopolymers such as lignin derivatives (by-products of pulp and paper industry). Lignin derivatives will both bind heavy metals into macromolecular complexes and significantly increase the solubility of many organic contaminants such as hydrocarbons and solvents. Because of this dual action, both the organic and inorganic contaminants will be mobilized and can easily be removed from the soil.

A series of bench-scale experiments were carried out by SAIC Canada using actual soil samples obtained from a site in Calgary, Alberta. After initial preparation procedure (drying and removal of oversized fractions) the samples were subjected to column leaching to simulate the in-situ flushing process. Lignosulfonates (LS), by-products of pulp and paper industry, were obtained from Tembec Sivichemicals Group of Tembec Canada. LS, which reportedly possess properties of surfactants, were added to leaching solutions to enhance the removal of hydrocarbons.

The leachate generated in the tests was collected and treated using membrane filtration. It was found to be effective for the leachate regeneration, to reduce the volume of the liquid waste (leachate) and recover water for re-use.

Goals, Outputs and Project Success Story

Bench scale testing is now completed. A work plan is now being developed to include a testing plan, a sampling plan, a health and safety plan and other relevant components that are required for the testing underway. The design and manufacture of a pilot-scale test system based on the results of the bench-scale tests carried out in 2002-2003 is scheduled to begin.

Funding

The average resources allocated for this project per fiscal year were $87,000 (2001-2002; 2002-2003). An average 68.4% of these resources came from PERD funds, the rest came from other sources (A-Base, industry). The average leverage quotient of total resources to PERD resources for the project was 1.5.

Profiles by Strategic Intent

Oil and Gas Sector

Remediation, Groundwater and Soil Issues

Attenuation of an Ethanol/BTEX Plume

Attenuation of an Ethanol/BTEX Plume in Fractured Bedrock Model Undergoing Biostimulation

Project Manager: Nathalie Ross

Project Objectives

This project stemmed from the PERD project "Biological Barriers in Fractured Bedrock". It focused on the effects of a potential groundwater pollutant, namely gasohol, on the biobarrier concept. The addition of ethanol in gasoline as an oxygenate is increasing in North America, and its effects on bioattenuation processes in groundwater had to be addressed. This project is part of the development of a biological barrier concept in fractured rock, involving partners from the NWRI (on fractured rock hydrology), Queen's University (on modeling), École Polytechnique de Montréal (on technology development), and University of Waterloo (on biodegradation and fate of gasohol).

This project is directly linked to PERD considerations on three specific aspects. First, the project will increase the knowledge on hydrocarbon interactions/fate/behaviour in groundwater flowing in fractured bedrock. Second, the biobarrier application will contribute to improve bioremediation technologies. Third, the biosafety assessment will contribute to the development of standardized toxicity tests. Considering that addition of ethanol in Canada is increasing, the question of groundwater remediation techniques meets also all Canadian citizen considerations.

This project benefits EC by addressing the mandate on "Clean Environment". It contributes to the NWRI's role by generating and disseminating scientific knowledge needed to resolve environmental issues of regional, national or international significance to Canada. The biotechnological aspects might benefit the New Substances Program specifically in providing data for the New Substances Notification Regulations.

Methodology

Validated input data will be obtained by conducting static tests (a series of microcosms), comparing the biodegradability of several ethanol-BTEX mixtures (varying from 1 to 10 %) by different groundwater microbial consortia. The effects of the biostimulation parameters (ex. nutrients) will also be measured. A statistical design will be applied to differentiate the significant factors. A Master's degree student from University of Waterloo will achieve the laboratory work conducted in a controlled temperature room (10 °C), located at NWRI.

Following the development of a biobarrier, an ethanol-BTEX plume will be injected in a glass fracture table (2.0 × 0.6 m, fracture = 1.5 mm) simulating a fracture plane intersected by a borehole. The capacity of the biobarrier to contain/degrade/resist to the plume will be measured by conducting tracer tests, monitoring contaminant concentrations, and analyzing biofilm constituents (exopolymeric substances, bacteria). To monitor the stability over time, the biobarrier will be maintained for a period varying from six months to one year. The experiments will be conducted in a controlled temperature room (10 °C), located at NWRI.

The evaluation of a battery of bioassays and molecular tools to monitor the changes in the environment will consist in screening a variety of bioassays and biomolecular analyses to propose a battery for the assessment of biobarrier safety. Regarding the bioassays, the approach will be to include well known tests, such as Microtox, and relevant organisms, such as wetland organisms, for groundwater assessment. Likewise, widely used biomolecular analyses, such as DGGE, and innovative methods, such as microarrays, will be screened.

Goals, Outputs and Project Success Story

Goals were set which resulted in the following outputs:

- Output 1: Validated input data for predictive models on biodegradation of ethanol-BTEX mixtures by groundwater micro-organisms (pertinent to bioattenuation modeling) (March 2003). Preliminary results from this experiment suggest a significant lag period for ethanol-BTEX biodegradation partially due to the presence of nutrients for biofilm growth;

- Output 2: Trial at a large scale labor[illegible]y of a "green" technology to bioattenuate an ethanol-BTEX plume (results availa[illegible]March 2004). A biofilm developed via biostimulation was tested at laboratory-scale to measure the effects of a BTEX/ethanol-contaminated groundwater plume on a mature biofilm and to assess the biodegradation/containment of these chemicals by the biofilm. A visible biofilm developed around the nutrient injection port after 32 days of biostimulation then reached maturity after 60 days;

- Output 3: Evaluation of a battery of bioassays and molecular tools to monitor the changes in the environment (important to meet new CEPA Regulations). This phase is ongoing.

This project is documenting the development of the biobarrier concept applied to fractured rock. Focusing on the effects of a gasohol plume, the results will help designing the application at full-scale. Preliminary results suggest a significant lag period for ethanol-BTEX biodegradation partially due to the presence of nutrients for biofilm growth. The confirmation of this hypothesis will be crucial for the design of biobarrier in contaminated environments. Fracture inflow and outflow samples revealed that ethanol and BTEX losses were low and could possibly be explained by adsorption to the biofilm. Further experiments are required to confirm the use of the biobarrier as a cut-off wall over its use as a bioreactive wall in fractured media.

Funding

The average resources allocated for this project per fiscal year were $260,000 (2002-2003 only). An average 32.7% of these resources came from PERD funds, the rest came from other sources (A-Base, others such as U. of Waterloo). The average leverage quotient of total resources to PERD resources for the project was 3.1.

Profiles by Strategic Intent

Oil and Gas Sector

Remediation, Groundwater and Soil Issues

Standardization and Validation of Terrestrial Toxicity Test Procedures

Standardization and Validation of Terrestrial Toxicity Test Procedures for Assessing Biological Effects in Hydrocarbon Contaminated Soils

Project Manager: Rick Scroggins

Project Objectives

The main objective of this project is to standardize new terrestrial soil toxicity test procedures using species relevant to the Canadian soil systems and field validate the toxicity tests using contaminated soils from facilities that produce natural gas and other alternative hydrocarbon-based fuels. This work directly supports some important programs at EC such as CEPA's Code of Good Environmental Practice for Industrial Site Decommissioning.

Methodology

In March 1995, Bonnell Environmental Consulting Ltd. completed a review of approximately 100 plants and soil-dwelling invertebrate species for relevance to Canadian soil systems and suitability as laboratory soil toxicity testing species. A short-list of species was recommended for the method development phase of the program. In the spring of 1995, a toxicology research team at the University of Guelph started a method development and refinement project directed at the four most suitable soil toxicity test procedures. This research included the testing of 33 terrestrial plants, 3 earthworms and 1 soil arthropod species. From May 1995 to July 1999, method research was conducted which resulted in the development of three test methodologies for assessing the toxicity of contaminated soil on earthworms, plants and a soil invertebrate using species important to healthy Canadian soil systems.

Since the completion of the principal method development phase, the newly developed soil toxicity tests have been further refined (eg: re-evaluation of the proposed test method validity criteria, testing alternative reference toxicants for quality assurance purposes and fine-tuning the recommended statistical guidance). The University of Guelph team will have completed this method refinement research before the end of the 2002/2003 fiscal year. Also, the first stage of method validation where the toxicity of different hydrocarbon mixtures in various agricultural and forest reference soils has been nearly completed by the University of Guelph. These reference soils are reflective of the general categories of Western Canadian soils.

As a parallel activity to the method refinement and validation efforts, two method writers have been contracted to prepare the standardized national test method documents for each of the new soil toxicity procedures. Dr. Don McLeay of McLeay Environmental Ltd. has been contracted to write the earthworm method while the terrestrial plant and soil arthropod methods are being prepared by Ms. Jennifer Miller of Miller Environmental Sciences Inc. Ms. Gladys Stephenson of the University of Guelph is acting as technical adviser to both method writers. To address key comments received from some expert reviewers, additional focused research has been commissioned to address uncertainties in the earthworm, terrestrial plant and collembolan soil arthropod methods at ESG/Stantec, École polytechnique fédérale de Lausanne (EPFL), and the ETC soil toxicology laboratories.

Goals, Outputs and Project Success Story

Inter-laboratory method validation testing is currently underway and involves 13 Canadian toxicology laboratories. The third phase of the earthworm method will be initiated in early February with plant test method round-robin testing scheduled for late February and March. A final draft version of each test method is required before the within-laboratory and between-laboratory variability can be quantified. Given the difficulties identified with one of the two species of choices of soil arthropods and further method development recommendations from the EC soil toxicology workshop held in February 2003 in Vancouver, the EPFL laboratory in Lausanne was contracted in July 2003 to conduct further method development research focused on: 1) soil pH measurement; 2) standard soil water measurement; and 3) the need to investigate the possibility of an alternative test species of the soil arthropod (specifically, *Folsomia fimetaria).* Research to address the first two issued stated above have been completed and the third activity is underway.

The main achievement for this project is the publication of three standardized toxicity test method documents as part of Environment Canada's biological test method series. These include:

- Test for toxicity to earthworms exposed to contaminants in soil
- Test for measuring seedling emergence and growth to terrestrial plants exposed to contaminants in soil
- Test for measuring survival and reproductive effects to collembolan in soil

The realistic completion date for English versions of the earthworm and terrestrial plant methods is April 2004, given the time needed for the formal editing process and completion of the various inter-laboratory round robin studies. Given the schedule for inter-laboratory testing for the soil arthropod method, a more realistic date for the English version of the formal test method is October 2004.

Funding

The average resources allocated for this project per fiscal year were $99,500 (2001-2002; 2002-2003). An average 74.9% of these resources came from PERD funds, the rest came from other sources (A-Base, CAPP). The average leverage quotient of total resources to PERD resources for the project was 1.3.

Assessment of Natural and Anthropogenic Impacts of Oil Sands Contaminants within the Northern River Basin

Project Manager: Kevin Cash and Joseph Culp

Project Objectives

This completed project stemmed from the Northern Rivers Basin (NRBS) Study and was related to the EC's large Ecosystem Initiative, the Northern Rivers Ecosystem Initiative (NREI). The objectives of this project included:

- Addressing the NRBS Board recommendations to Ministers regarding oil sands contaminant fate, distribution and impacts in the northern basins area;
- Providing an improved understanding of the nature and extent of natural hydrocarbon releases to the environment within the oil sands region of northern Alberta;
- Distinguishing between effects related to natural versus anthropogenic releases of oil sands contaminants to the environment;
- Developing and field validating ecological tests that provide early warning of the impacts of oil sands-related contaminants on biota;
- Evaluating these and other currently available tests for inclusion in an environmental effects monitoring program for the oil sands industry.

This project benefited EC since it addressed major research recommendations contained in the Minister's response to the NRBS. This project assessed and predicted potential impacts of hydrocarbon activities occurring in the Alberta oil sands area and distinguished these impacts from those produced by naturally occurring hydrocarbon deposits and releases.

Methodology

To evaluate the impacts of hydrocarbon activities and those produced by naturally occurring hydrocarbon, the following steps were studies were undertaken:

- Chemistry and ecotoxicology of organic compounds in bitumen froth relating to long-range transfer in oils sands operations.
- Identification and characterization of natural hydrocarbon release from oil sands deposits in the northern river basins area.
- Long-range transport of hydrocarbons to the northern deltas and lakes: pathways and fate.
- Ecological effects of natural releases of oil sands contaminants on benthic macroinvertebrates.

Fish health effects from oil sands wastewater discharges and naturally-occurring oil sands compounds in the Athabasca river system.

- The ecological viability of constructed wetlands at suncor: population and health-related considerations in birds.

Goals, Outputs and Project Success Story
The project now completed included the following significant findings:

- EROD activity in rat livers exposed to bitumen froth was low compared to that measured in benzo[a]pyrene (BaP). The maximum likely concentration of representative polycyclic aromatic compounds in receiving waters in the event of a spill of bitumen froth was also calculated to be low (i.e. < 20 μg/L).

- Studies confirmed that the tributaries passing through the Fort McMurray oil sands regions contain significant levels of naturally derived hydrocarbons, likely derived from natural oil- seeps in the regions. Once the tributaries converge with the mainstem rivers concentrations rapidly fall to values (< 0.01 μg/g) typical of remote pristine areas.

- Sediments in the Athabasca River, its tributaries, downstream deltas and western Lake Athabasca do indicate the presence of petrogenic PAHs. However, there is no evidence of impacts from the oil sands operations on hydrocarbon distributions and sediment toxicity.

- Evidence suggests that exposure to naturally-occurring PAHs, as a result from exposed oil sands deposits, may have a slight to moderate detrimental effect on benthic invertebrates as revealed by reduced density and community composition in field samples and reduced survival and growth in laboratory toxicity tests. However, the observed patterns do not suggest a major negative impact of exposure on these invertebrates to naturally-occurring oil sands materials.

- There do appear to be differences in the fish reproductive indicators (decreased sex steroid production by testes and ovaries of slimy sculpin) of oil sands exposed fish from the Steepbank River in the vicinity of anthropogenic disturbance. As well, metabolic bioindicators (MFO) in slimy sculpin showed differences between oil sands and reference sites. SPMDs showed presence of MFO-inducers in the Athabasca River, as well as potent inducers in the oil sands refinery wastewater discharge. Additional studies are required to assess the full impact of these impacts.

Funding
The average resources allocated for this project per fiscal year were $158,500 (2001-2002; 2002-2003). An average 51.1% of these resources came from PERD funds, the rest came from other sources (A-Base, industry and in-kind). The average leverage quotient of total resources to PERD resources for the project was 2.0.

Land Farming of Bioremediated Hydrocarbon Contaminated Soils/Wastes

Project manager: Terry McIntyre

Project Objectives

The overall goal of this project is to establish a new site using bioremediated hydrocarbon contaminated soils to develop a best management practice for handling bioremediated hydrocarbon contaminated soils.

EC will benefit from this research since environmental assessments associated with land application of bioremediated hydrocarbon contaminated soils can be completed and the information generated through this study will define a realistic endpoint for bioremediation of hydrocarbon contaminated soils/wastes.

Methodology

This project will select the best crop coverage on soils with hydrocarbon residues based on the crop yield and its impacts on hydrocarbon residues; collect surface runoff from new established research plots and determine their toxicities using a simple bioassay. In addition we will assess the movement of hydrocarbon residues to ground water by flooding existing site.

Goals, Outputs and Project Success Story

From this research, there is now a more complete understanding of the role of land farming as a remediation technology or option for the Canadian petroleum and gas industry. Sufficient empirical data has been collected to establish both a realistic endpoint for bioremediation of hydrocarbon contaminated soils / wastes and to recommend a sound-crop management practice for land owners employing land farming as a remediation option of choice.

Funding

The average resources allocated for this project per fiscal year were $43,000 (2001-2002; 2002-2003). An average 65.1% of these resources came from PERD funds, the rest came from other sources (A-Base). The average leverage quotient of total resources to PERD resources for the project was 1.5.

Toxicity Workshop

Project Manager: Rick Scroggins

Project Objectives

In February 2003, Environment Canada hosted a 3-day workshop on the toxicological assessment of Canadian soils and development of standardized test methods. The workshop was held at Pacific Environmental Sciences Centre in North Vancouver. Forty experts from Europe, the United States and Canada participated in the workshop. The assembled expertise covered soil toxicology, microbiology, soil chemistry, earth sciences, soil ecology, plant physiology, risk assessment, regulation of contaminated lands, and contaminant interactions in soil.

The main objective of the workshop was the identification of priorities for method development, validation and standardization that will lead to a second generation of soil toxicity test methods for assessing the effects of contaminated soils. Another objective was to provide concrete recommendations on how to test non-agricultural soils as part of a laboratory test methodology (i.e., testing soils representative of boreal and carolinian forests, wetlands, Muskeg, northern areas such as taiga or tundra and other wild lands).

Three main work groups were formed for the purpose of discussion. Working Group 1 dealt with "Alternative species and procedural modifications of existing terrestrial toxicity test methods, Working Group 2 dealt with "Laboratory functional assays and exposure systems for site soil assessment, and Working Group 3 discussed "Physicial or biological factors influencing the results of soil toxicity tests".

The principal subject addressed by Working Group 1 was possible modifications to existing Environment Canada and international soil test methods as well as the potential for using alternative species in amended versions of these methods. The working group discussed many issues including the use of soil amendments, use of reference soils from non-agricultural habitats, choice of reference toxicant, test design, addition of food during tests, standardized procedures for pH measurement, and standard approaches for determining soil moisture. Working group members agreed that each of the above issues should be clearly addressed in any standardized soil toxicity test method and that further research would be needed to resolve some of these issues.

Participants of Working Group 2 defined functional assays as assays that assess the direct and indirect effects of contaminants to biologically-mediated processes in soil. participants of Working Group 2 agreed that functional assays should be part of the test battery used to develop soil quality criteria because they a) reduce false positives, b) enhance communication with stakeholders and c) increase the reliability of expert judgments. However, functional assays should be used in conjunction with single species assays and not be used as a stand-alone test. As part of the development of standardized functional assays, the participants agreed that standardized microcosm test methodologies based on published methods need to be further developed and evaluated in a regulatory context.

The objectives of Working Group 3 included critical evaluation of strengths and limitations of current and potentially promising approaches used in laboratory-based ecotoxicity testing to assess the state of soil ecosystems at contaminated field sites. The discussion topics focused on issues related to the effects of soil properties on soil biota responses to contamination, possible approaches to account for variability across extremes in chemical and physical soil properties, developing guidance on experimental design for assessing toxicity of contaminated field soils, review of the emerging approaches for soil ecotoxicity evaluation, and relevance of ecotoxicity test methods for risk management/policy decisions. Working Group 3 generally agreed that experimental design of exposure conditions for test species should most closely approximate bioavailability of a contaminant or mixture of contaminants in the site's soil. For that reason, the group recommended that highest priority should be given to the use of pre-existing contaminant concentration gradients from the site to investigate concentration-response relationship. The serial soil dilution approach may be used when reference material of the same soil type and horizon is available.

Further details on the Vancouver workshop discussions will be provided through a series of presentations proposed for the SETAC session on "Assessing Contaminated Site Soils" during the 24th Annual North American SETAC Meeting in Austin, Texas.

Funding

The average resources allocated for this project per fiscal year were $42,500 (2001-2002; 2002-2003). An average 47.1% of these resources came from PERD funds, the rest came from other sources (A-Base). The average leverage quotient of total resources to PERD resources for the project was 2.1.

Strategic Intent 2—Transportation Sector

Strategic Intent 2 is to foster cleaner sustainable transportation fuels and systems in order to improve the environment, reduce emissions, including GHGs, and to increase economic activity through development of domestic and export markets.

Strategic Intent 2 · Strategic Direction 1

Strategic Direction 1 is to provide S&T to reduce emissions from transportation sources to improve air quality and health and reduce GHG production.

Strategic Intent 2 · Strategic Direction 1 · Objective 2.1.1

Support for the Development of Technological and Other Measures to Control and Reduce Emissions of Particulate Matter.

POL 2.1.1—Air Quality- Particles Research

Air quality, especially for city dwellers, is an ongoing, high profile area of environmental concern. The outcome of research in this area is ultimately to bring a reduction in the amount of PM (particulate matter) released from transportation sources and result in better health for millions of Canadians. The goal of the Particles POL 2.1.1 is to provide knowledge and tools that will support the development of technological and other measures to control and reduce emissions of particulate matter from transportation sources. POL 2.1.1 is a coordinated group of research activities that deal with the improvement and understanding of particulate matter formed as a result of transportation. The research is focused on how the particles and their precursors are transformed and transported in the atmosphere, and how transportation-related particles affect public health.

Issues surrounding PM are being investigated by several projects such as one EC PERD sponsored project which aims at improve sampling methods, chemical analysis techniques, and to assemble a workable data baseline. Follow-up work extends the research by more fully characterizing the particles emitted and by filling data gaps, in an effort to palliate to our incomplete knowledge of the influences of changing technology, fuels, and transportation policies on PM emissions. This EC project will also study the emission rates of elemental carbon from light duty vehicles, a source of PM which has not been extensively studied that can be important in areas where the diesel fleet is small. A project led by NRC involves the LII or Laser-Induced Incandescence for online exhaust PM monitoring: new application; measure aggregate particle size and individual particle size- has been commercialized by Artium Technologies Inc.

Projects such as this one have drawn the support of numerous federal departments and agencies, of the Toxic Substance Research Initiative, and of industry. The outcome of these efforts should bring a reduction in the amount of PM released from transportation sources and result in better health for millions of Canadians, from improved air quality. A critical milestone was achieved in the Health Effects activity by Health Canada with the near completion of a survey that will serve as the basis of future work linking chronic exposure to atmospheric pollutants to health impact.

Profiles by Strategic Intent

Transportation Sector

Control and Reduction of Particulate Matter Emissions

The following activities are included under POL 2.1.1:

- Emissions- Develop technology to measure and control the formation and emission of particles and their precursors by transportation-related combustion sources
- Ambient Air- Develop measurement and modeling techniques and systems for atmospheric particles and their precursors produced by transportation-related combustion sources
- Health Effects- Examine acute and chronic cardio-respiratory effects on humans of particles produced by transportation-related combustion sources

International collaboration is also an important part of this POL, as the LII group (Laser-Induced Incandescence technology, a project in the Emissions activity) at NRC participates in the Particulate Matter Collaboratory as an international effort with Sandia National Laboratories and Artium Technologies. Negotiations for a Trilateral Energy Cooperation Agreement in Science and Technology and identified particulate measurement research as an area for collaboration between Canada, U.S. and Mexico

Projects in this POL have drawn support of numerous federal departments and agencies, such as NRCan, EC, HC, NRC, DND, NRCC of the Toxic Substance Research Initiative, as well as cooperative funding from industry.

For 2001-2002 and 2002-2003 , the POL plan included 7 individual projects. In 2002-2003, POL 2.1.1 was in its third year of the established POL Plan. EC was leading 2 of these projects, both in the Emissions Activity .

The total 2001-2002 annual budget for POL 2.1.1 was $2,418,000 and $2,444,000 for 2002-2003. The total PERD resources available for 2001-2002 were $715,00 and for 2002-2003, $759,000. PERD funds were divided amongst the departments involved in this POL (see Table 6). For this POL, the leverage quotient of total resources to PERD resources for 2001-2002 was 3.4 and 3.2 for 2002-2003.

Table 6. Percentage of PERD Funds for POL 2.1.1 Allocated to Each Department

Department	Percentage of Funds (%)	
	2001–2002	2002–2003
EC	51.6	39.4
NRC	27.8	32.4
HC	11.6	14.2
DND	9.0	8.4
Management EC	—	5.5

Environment Canada Projects for POL 2.1.1

Characterization of Particles and Precursors in Emissions

Project Manager: Lisa Graham

Project Objectives

This project is part of the Emissions Characterization activity within POL 2.1.1 which involves three departments. The emissions characterization research will contribute to improvement of air quality models by addressing knowledge gaps and providing data for model development and evaluation. Of particular interest are the characteristics (mass, size distribution and chemical composition) of primary particle emissions, chemical speciation profiles for gaseous emissions and a better understanding of the chemistry and physics of aerosol formation. This work falls within the PERD objective to develop technology and other means in order to control and reduce emissions of particulate matter.

This project will benefit EC in addressing the inadequacies in vehicle emissions profiles; this knowledge gap make it difficult to assess proposed vehicle technology or fuel formulation changes. This can be seen in the recent assessment by the CCME Task Force on Cleaner Vehicles and Fuels of the impacts and benefits of reducing sulphur in gasoline. The lack of representative emissions profiles results in uncertainties that hamper decisions and, in the long-term, will hinder Canada's progress toward a sustainable energy future.

Methodology

To carry out emissions measurements, the following data is gathered:

- Physical characterization of size distributions and number concentrations of particles emitted from traditional, new technology and alternative fuelled vehicles;
- Chemical characterization of particles and gaseous precursors;
- Investigation of transportation tracers for analysis of ambient particles and to support model development;
- Measurement of the effect of sulphur levels on ammonia emissions; and
- Investigation of the contribution of lubrication oils to particulate matter.

The emissions measurement activities make use of the suite of analytical tools developed by NRCan-CETC and EC-AAQD for the current PERD program. This work will be carried out by staff of the Environmental Technology Centre of EC.

Goals, Outputs and Project Success Story

Goals set for this project include the development of technology to measure and control the formation and emission of fine particles and their precursors by transportation-related combustion sources, specifically by sampling and analytical techniques for fine particles and their precursors in exhaust of representative vehicle classes. The emissions data gathered in this project is being applied to improve modelling of particle chemistry and physics. There has been close collaboration with model developers that is influencing the development of aerosols module.

Funding

The average resources allocated for this project per fiscal year were $379,500 (2001-2002; 2002-2003). An average 44.9% of these resources came from PERD funds, the rest came from other sources (A-Base, others, plus $6,000 from U. of British Columbia). The average leverage quotient of total resources to PERD resources for the project was 2.2.

Characterization of Particles in Ambient Air

Project Manager: Jeff Brook

Project Objectives

This project is part of the Ambient Air activity. The overall goal of the ambient air particle characterization project is to gain new insights into the transport, transformation and fate of ambient fine particles and their precursors, particularly those produced by emissions from the transportation sector. The project will build upon previous work on characterizing vehicle emissions and developing improved analytical and ambient sampling methods, coupling these with improved data analysis techniques to:

- improve understanding of the influences of transportation sources on the concentrations of PM$_{2.5}$ and related gaseous constituents in, and downwind of, major Canadian cities; and
- provide improved data for the development and evaluation of air quality models used to predict ambient particles concentrations.

This work falls within the PERD objective to develop technology and other means in order to control and reduce emissions of particulate matter.

This project will benefit EC by increasing the knowledge base of ambient fine particles and precursors which will strengthen scientific support to policy and regulatory development and ultimately give cleaner air and reduced health effects due to decreases in Emissions of primary particles and gaseous precursors from transportation-related combustion sources.

Methodology

The project will participate in a major field campaign (Pacific 2001) in order to evaluate and refine the sampling, analytical and data analysis methods under development. Field data collected in this project will be applied to produce direct estimates of the role of transportation and to determine the nature and source of carbonaceous fine particles. The characterization of particles in ambient air includes the 2 following steps:

1) Development of new air sampling and analytical chemistry techniques for particles, including;

- sampling methods to reduce PM sample collection artifacts due to semi-volatile organic compounds;
- analytical methods to determine the chemical characteristics of particles that relate to their source or to important atmospheric processes that affect particle formation; and
- development of improved semi-continuous and integrating methods for measurement of organic and elemental carbon.

2) Compilation and analysis of ambient measurement data sets in order to;

- develop and test various hypotheses regarding the influence of transportation sources on PM2.5 concentrations; and
- support the development and evaluation of air quality models.

The work will be carried out at the Air Quality Research Branch of EC.

Goals, Outputs and Project Success Story

The main goal of this project is to develop measurement and modeling techniques and systems for atmospheric particles and their precursors produced by transportation-related combustion sources. Specific targets which have been achieved include the completed analysis of tracers for wood combustion, meat cooking and fungi. A full year of daily TSRI (Toxic Substances Research Initiative) samples were analyzed. The Pacific 2001 field study was successful and have shown that marine emissions can be significant contributors to PM in the Georgia Basin. Receptor modeling results was presented to various stakeholders whereas the receptor modeling results are being utilized in planning for the Canada-US PM Annex.

Funding

The average resources allocated for this project per fiscal year were $482,700 (2001-2002; 2002-2003). An average 20.9% of these resources came from PERD funds, the rest came from other sources (A-Base, others). The average leverage quotient of total resources to PERD resources for the project was 4.8.

Strategic Intent 2 ·Strategic Direction 1 · Objective 2.1.2

Profiles by Strategic Intent

Transportation Sector

Design of Fuels to Achieve Emission Reductions

The design and use of gaseous and liquid hydrocarbon fuels and associated technologies to achieve emissions reductions.

POL 2.1.2—Advanced Fuels and Transportation Emissions Reduction (AFTER)

The impact transportation has on our environment is being critically examined and as a result the transportation industry is being asked to find ways to reduce this impact through the development of new, cleaner technologies. As projections see a continuing increase in miles driven and a trend for use of larger vehicles, the need for a cleaner environment and further emissions reductions is ever increasing. The Advanced Fuels and Transportation Emissions Reduction (AFTER) POL supports the development of new, innovative transportation technologies in order to reduce emissions and produce a cleaner environment. The primary impact from the AFTER research and development (R&D) program is improved air quality through reduced emissions from the Canadian transportation sector This includes regulated emissions VOC, CO, NOx and PM (volatile organic compounds, carbon monoxide, oxides of nitrogen and particulate matter) as well as greenhouse gas (GHG) emissions. This POL also assists in the growth of commercially viable new Canadian technologies.

Some highlights of the work carried out in this POL include an EC project that is demonstrating the significant fuel economy benefits of faster engine warm-up during winter operations. One of the prototype technologies that were evaluated for cold start diesel emission reductions is presently being commercialized. Another EC lead project testing gasoline/ethanol blends (up to 20% ethanol content) showed statistically significant reduction in CO emissions but at the same time NO_x and aldehyde levels increased; the test programs are on-going. A project enabling EC to have a direct input into the selection of potential diesel additives has tested over 25 of these additives, contributing to a database of ethers properties of over 172 products. An examination of the toxicology of three new potential diesel ethers showed no toxic effects with these compounds. Industry is now being sought for the synthesis of these reduced emissions fuels. These projects are all leading the transportation industry towards cleaner technologies.

The following activities are included under POL 2.1.2:

- Gaseous and Alternative Fuels Technology
- Gasoline and Spark Ignited Engine Technology
- Advanced Diesel Fuels and Compression Ignition Engine Technology

International collaboration within this POL extends not only to work on jointly funded projects but also to exchanges of information and/or use of facilities. For example, the Future Transportation Workshop held in Windsor, Ontario was jointly funded with the US Department of Energy. An evaluation of the Enhanced Ignition System under development by Nexum was carried out at the University of Texas in Austin, Texas. The AFTER POL also supported participation with the International Energy Agency (IEA).

Profiles by Strategic Intent

Transportation Sector

Design of Fuels to Achieve Emission Reductions

Funding sources and collaborations for projects in this POL include the following federal departments: NRCan, TC, EC, HC, NRC. The AFTER POL has established many partnerships with industry and some universities (University of Waterloo, University of Texas) and the Canadian Petroleum Products Institute.

For 2001-2002 and 2002-2003, the POL plan included 30 individual projects. In 2002-2003, POL 2.1.2 was in its third year of the 5-year established POL Plan. EC is leading 5 of these projects.

The total 2001-2002 annual budget for POL 2.1.1 was $3,722,000 and $3,793,000 for 2002-2003. The total PERD resources available for 2001-2002 were $1,786,000 and for 2002-2003, $1,786,000. PERD funds were divided amongst the departments involved in this POL (see Table 7). For this POL, the leverage quotient of total resources to PERD resources for 2001-2002 was 4.3 and 3.1.

Table 7. Percentage of PERD Funds for POL 2.1.2 Allocated to Each Department

Department	Percentage of Funds (%)	
	2001–2002	2002–2003
NRCan	33.9	34.3
TC	22.3	15.4
NRC	20.0	25.6
EC	10.4	10.2
HC	12.0	11.9
Planning & Support	1.4	—
Support & Evaluation	—	1.0

Environment Canada Projects for POL 2.1.2

Engine Cold Start Efficiency

Project Manager: Fred Hendren

Project Objectives

This work is now complete. It supports the objectives of PERD by conducting R&D on technologies and/or processes that have the potential to reduce energy consumption and use energy more efficiently. The end result will be a technology or process that will be transferred to industry for commercialization.

EC benefits from this work through the development of technologies/processes that will reduce the pollution burden from mobile sources. The result would be improved air quality in urban areas. In addition, the data that are being generated from this study will enhance the department's knowledge base on exhaust emissions from the Canadian fleet under cold operating conditions. The work also is directly related to environmental protection, enhancement, and climate change initiatives under the Kyoto agreement.

Methodology

The study is being undertaken by conducting vehicle cold start exhaust emissions and fuel consumption testing in an EC test laboratory. The testing involves an evaluation of various technologies and processes that have indicated the potential for energy consumption reductions through an extensive literature search.

Goals, Outputs and Project Success Story

The outputs from this work will be technologies or a technology and processes that will result in reductions in energy consumption for automobiles, primarily, but also for trucks. If a process is developed the government could use this process to inform the public on how to save energy. The measurement of success is the demonstration of methods that will reduce the amount of fossil fuels that are consumed during engine cold start. The target is 10% reduction.

One of the prototype technologies (variable coolant flow controller and engine heating elements) that were evaluated for cold start diesel emission reductions is presently being commercialized.

Funding

The average resources allocated for this project per fiscal year were $45,000 (2001-2002; 2002-2003). 100% of these resources came from PERD funds. The leverage quotient of total resources to PERD resources for the project was 1.0.

Profiles by Strategic Intent

Transportation Sector

Design of Fuels to Achieve Emission Reductions

Measurement of Toxic Emissions

Measurement of Toxic Emissions from Ethanol/Gasoline Blend Fuels

Project Manager: Greg Rideout

Project Objectives

The Government of Canada is supporting through various mechanisms the introduction of ethanol as a low level blend additive for gasoline. The overall objective of the AFTER POL is to support the development of new, innovative technologies, standards and regulations to reduce emissions from the transportation sector.

The objective of this project is to develop the data that is necessary to assess the environmental and health benefits of ethanol when used in light duty vehicles in Canada, under Canadian operating conditions. The output of this project will be the data that is necessary to evaluate the air quality impacts of ethanol blended gasoline for greenhouse gases, air toxics, smog precursors, and fine particulate.

EC benefits from this work through the development of technologies/processes that will reduce the pollution burden from mobile sources. The result would be improved air quality in urban areas. In addition, the data that are being generated from this study will enhance the department's knowledge base on exhaust emissions from the Canadian fleet under cold operating conditions. The work also is directly related to environmental protection, enhancement, and climate change initiatives under the Kyoto agreement.

Methodology

The study is being undertaken by conducting light duty chassis dynamometer emission testing and fuel consumption testing at standard and cold temperatures in an EC test laboratory. In addition the testing will examine the effects of these fuel blends on the evaporative emissions which are a significant source of smog precursors in Canadian cities.

Goals, Outputs and Project Success Story

The outputs from this work will be a comprehensive database of exhaust and evaporative emissions for various gasoline-ethanol blends. Testing of gasoline/ethanol blends with up to 20% ethanol content has confirmed a statistically significant reduction in CO emissions but also an increase in NO$_x$ and acetaldehyde emissions. The test program is continuing with an examination of emissions during engine start-up as well as those emitted through evaporation.

Funding

The average resources allocated for this project per fiscal year were $125,000 (2001-2002; 2002-2003). An average 80% of these resources came from PERD funds, the rest came from other sources (A-Base and industry). The average leverage quotient of total resources to PERD resources for the project was 1.3.

Environmental Properties of Ether Fuels

Project Manager: Merv Fingas

Project Objectives

Environmental Properties of Ether Fuels stems from the AFTER project which looks at emissions from diesel engines and possible alternatives. The objectives of this project include:

- To screen potential diesel ethers for environmental concerns related to water and soil;
- To measure environmental properties of diesel ethers, particularly water solubility.
- To measure the environmental toxicity of potential candidate ethers.

The project provides Environment Canada a direct input into the selection of potential diesel additives and allows EC to include their own criteria into the selection process. The project addresses federal government priorities in the transportation area including the reduction of GHG emissions. It is also beneficial to EC because it addresses the federal government's responsibility for transportation emission regulations through the new CEPA legislation; R&D in this area is necessary for the development of new regulations.

Methodology

The method is to conduct laboratory studies on potential diesel additives. Specific outputs will be achieved through accumulation of and correlation of literature values of potential ethers. The solubility of the candidate ethers will be measure and correlated with physical properties to yield a correlation scheme. The environmental concerns will be dealt with by screening with microtox, degradation, and aquatic toxicity test.

Goals, Outputs and Project Success Story

The research has led to the demonstration of one non-toxic ether as a high cetane blending component for low emissions diesel fuel. Over 25 potential diesel additives have been tested for solubility, aquatic toxicity, and biodegradation potential. Two reports on these results have been published.
Three potential new ethers show no toxic effects. Database of ethers properties now includes 172 products. A method for solubility measurement has also been perfected and published.

Funding

The average resources allocated for this project per fiscal year were $56,000 (2001-2002; 2002-2003). An average 46.4% of these resources came from PERD funds, the rest came from other sources. The average leverage quotient of total resources to PERD resources for the project was 2.2.

Profiles by Strategic Intent

Transportation Sector

Design of Fuels to Achieve Emission Reductions

Windsor Workshop Support

Windsor Workshop Support

Project Manager: Greg Rideout

Project Objectives

The main objective of the Windsor Workshop is the exchange of technical information on transportation fuels. This information will result in the development of new, cleaner transportation technologies that will reduce emissions and produce a cleaner environment.

EC provides support to the Windsor Workshop on Transportation Fuels. This workshop is well recognized for the exchange of technical information relating to developments in conventional transportation fuels as well as alternate fuels, advanced automotive technologies, vehicle emissions, and combustion processes.

A successful joint workshop with the US DOE held in May 2002 (Windsor, ON) brought together members of Government, Industry and Academia.

Funding

The resources allocated for this project per fiscal year were $10,000 (2001-2002; 2002-2003). 100% of these resources came from PERD funds. The average leverage quotient of total resources to PERD resources for the project was 1.0.

Profiles by Strategic Intent

Transportation Sector

Development of Fuel Cell, Electric, and Hybrid Vehicles

Strategic Intent 2 ·Strategic Direction 2

Strategic Direction 2 is to provide S&T to improve energy efficiency, reduce emissions, and provide economic benefits to Canada from next generation vehicles and systems.

Strategic Intent 2 ·Strategic Direction 2 ·Objective 2.2.2

The Development of Fuel Cell, Electric, and Hybrid Vehicle Components and their Supporting Infrastructures.

POL 2.2.2—Fuel Cells, Electric and Hybrid Vehicles

The Fuel Cells, Electric and Hybrid Vehicles POL focuses on the development of fuel cell, electric and hybrid vehicle components and their supporting infrastructures. The need for emissions reduction and ultimately a cleaner environment as well as providing economic benefits to Canada is the pillar of POL 2.2.2. Activities within this POL are progressive, starting at the stage of innovation, leading to the stage of product development, and finally to the introduction of the new technology.

To produce market ready components and systems, and develop infrastructure to support their commercialization, the following activities carried out by NRCan, DND, TC, EC or HC are included under POL 2.2.2:

- Investigation of promising new technologies: fundamental research focusing on lab-scale projects (e.g. Improvement the Nickel hydroxide cathode). Successful technologies move on to Activity 2 where industry further develops the product.

- Development and testing of laboratory and prototype components and systems: producing outputs such as (1) prototype power sources (fuel cells, batteries, flywheels, etc), and (2) prototype control systems, auxiliaries and driveline technology (e.g. hybrid vehicle controls or electric motors) and their integration. For example, TC had developed a multi-mode electric bus in partnership with industry. Several transit properties have shown interest in the OCC bus (Overland Custom Coach) and commercialization opportunities are likely to unfold in the near future.

- Investigation of health, safety and environmental issues to provide a knowledge base for the development of infrastructure (including policies, standards and guidelines): focusing on facilitating the introduction of electric vehicle technology. Projects undertaken in this activity have assessed the possible air quality effects of significant penetration of electric vehicles within two urban areas of Canada; in both locations, overall GHG and non-GHG emissions would be improved. Results could also be extrapolated to full cell vehicles over the next few years. EC is contributing to a joint program with NY State to evaluate clean diesel technologies for NY City Transit Fleet. The outcome of that work is the advanced introduction of ultra-low sulfur diesel fuel, emission control technologies, and diesel.-electric hybrids in NY City. These technologies are now being taken up by various municipal transit operations across the country.

This POL is led by the NRCan's CANMET Energy Technology Centre (CETC). Other funding sources and POL participants include EC, HC and TC. The industrial partners working with the POL are numerous and include Armstrong, Monitoring, Agile Systems Inc, BET Services Inc., CAMI Automotive Inc., Dynetek Industries Ltd, Electrovaya Inc., Flywheel Energy Systems Inc, Ford Motor Company, etc. The Universities of Queen's, McMaster, Waterloo and the Royal Military College participate in a number of projects. The province of Manitoba, and the municipalities of Montréal, Québec, St-Jérôme and Toronto also support some projects.

In 2002-2003, POL 2.2.2 was in its third year of the 3-year established POL Plan. EC is leading 1 of these projects. This POL will be combined with POL 2.2.3 "Hydrogen Production, Storage and Infrastructure" in fiscal year 2003-2004. Each POL will operate largely independently for the first year.

The total 2001-2002 annual budget for POL 2.2.2 was $12,084,000 and $8,747,000 for 2002-2003. The total PERD resources available for 2001-2002 were $2,804,000 and for 2002-2003, $2,692,000. PERD funds were divided amongst the departments involved in this POL (see Table 8). For this POL, the leverage quotient of total resources to PERD resources for 2001-2002 was 4.3 and 3.1 for 2002-2003.

Table 8. Percentage of PERD Funds for POL 2.2.2 Allocated to Each Department

Department	Percentage of Funds (%)	
	2001–2002	2002–2003
NRCan	76.9	75.6
DND	10.8	10.6
TC	8.9	8.7
HC	3.4	3.3
EC	—	1.7

Environment Canada Projects for POL 2.2.2

Profiles by Strategic Intent

Transportation Sector

Development of Fuel Cell, Electric, and Hybrid Vehicles

Measurement of Toxic Emissions

Measurement of Toxic Emissions from Fuel Cells, Electric, and Hybrid Vehicles

Project Manager: Greg Rideout

Project Objectives

This work is undertaken as part of a bigger project or program. The ERMD is working with industry and other government departments in the development and demonstration of fuel cell, electric, and hybrid vehicle systems. The PERD contribution is directed toward the scope of the emissions testing element of these projects to expand upon the characterization of toxics, greenhouse gases, and particulates.

In the past year the work was focused on three efforts:

- A Fuel Cell project that was undertaken with Georgetown University;
- A diesel-electric hybrid bus project undertaken with Allison-GM, and the Southeaster Pennsylvania Transportation Authority;
- A Transport Canada project with Overland Coach.

This work supports the objectives of PERD by conducting R&D on technologies and/or processes that have the potential to reduce energy consumption and use energy more efficiently. The end result will be a technology or process that will be transferred to industry for commercialization

EC benefits from this work through the development of technologies/processes that will reduce the pollution burden from mobile sources. The result would be improved air quality in urban areas. In addition, the data that are being generated from this study will enhance the department's knowledge base on exhaust emissions from the Canadian fleet under cold operating conditions. The work also is directly related to environmental protection, enhancement, and climate change initiatives under the Kyoto agreement.

Methodology

The study is being undertaken by conducting heavy duty chassis dynamometer emission testing and fuel consumption testing in an EC test laboratory. The testing involves an evaluation of various technologies and processes that have indicated the potential for energy consumption and emission reductions.

Goals, Outputs and Project Success Story

The outputs from this work will be a comprehensive database of emissions and performance characteristics for the various technologies that can then be compared to data from conventional vehicles under the same test conditions. This information is needed by the technology developer, the fleet manager as well as the government policy planner. At each level the data is applied to make informed investment decisions in terms of technology advancement, fleet investments, and government policy or regulation.

The data from this work is being added to that developed under a joint EC-NY State program to evaluate clean diesel technologies for the NY City Transit Fleet. The outcome of that work is the advanced introduction of ultra-low sulfur diesel fuel, emission control technologies, and diesel-electric hybrids in NY City. Through this program several other large northeastern US cities, i.e. Philadelphia, Washington, and Boston, have made similar investment decisions. The Canadian benefit is that these technologies are now being taken up by various municipal transit operations across the country.

Funding

The average resources allocated for this project per fiscal year were $105,000 (2002-2003 only). An average 47.6% of these resources came from PERD funds, the rest came from other sources (A-Base, industry). The average leverage quotient of total resources to PERD resources for the project was 2.1.

Strategic Intent 2 ·Strategic Direction 2 · Objective 2.2.4

Optimization of the Energy Efficiency of Transportation Systems.

POL 2.2.4
Transportation accounts for approximately 25% of GHGs in Canada (50 % distribution between urban and inter-city transportation). Urban transportation is responsible for 78% of emissions, and the remaining 22% from freight movement within urban areas. POL 2.2.4 develops knowledge, new concepts and technologies that will improve energy efficiency and reduce GHGs, as well as other emissions.

Information and communications systems (ICS) play an important role in improving the energy efficiency associated with the interaction and integration of vehicles, operators and transportation infrastructure. Transportation systems can incorporate many technologies and operating concepts such as sensors, communications, control, vehicle or vessel location identification, navigation, data storage, processing and display and improved operating procedures. For example, a joint project was initiated between TC with the Ministry of Transportation of Ontario (MTO) with the ultimate objective of improving the efficiency and effectiveness of Advanced Traffic Management Systems (ATMS) through advances in automated incident detection systems and other traffic management strategies. A project was also initiated on Aircraft Meteorological Data Relay (AMDAR) which will enable more accurate meteorological forecasts which in turn lead to more efficient air travel, with reduced fuel consumption and GHG emissions.

Through reduced congestion, integration of different modes, increased capacity of the existing infrastructure, shifting of traffic to less energy intensive modes, energy consumption can be reduced. Application of new knowledge and technologies to transportation will also provide economic benefits. Canada has been a leading player in a number of new system concepts and technologies such as toll collection, weigh-in-motion, traffic sensors, vehicle transponders, vehicle traffic management and communication systems.

In the navigational transportation area, the St. Lawrence system is used as a prototype to resolve optimal navigation routes in terms of fuel consumption and CO_2 pollution reduction, and at supporting traffic management. EC's project on St. Lawrence Routing management has developed ice transit performance algorithms which will result in fuel savings of 9.74%. In a normal winter, this is equivalent to at least 25,000 tons reduction in CO_2 for the St. Lawrence system.

The following activities are included under POL 2.1.2:

- Urban Transportation Efficiency
- Intermodal Freight Efficiency
- Air Transport Efficiency
- R&D on Future Opportunities

Canadian participants in the FDM Program are continuing to co-operate with organisations in other countries in the development of policies, methods, tools, and sharing of the results. There is joint collaboration and harmonization between US, Canada and European countries

Profiles by Strategic Intent

Transportation Sector

Energy Efficiency of Transportation Systems

in developments of GPS and SatNav. Several countries meet regularly to share information and results related to AMDAR.

Participating federal departments include TC, DFO, EC, NRC and NRCan. Funding and collaboration in this POL includes industry (Air Canada, Air Norterra, Bell Mobility, Bombardier, Domtar, Nav Canada, Novax Industries, and many more) as well as provincial governments and agencies (Government of Alberta, Transport Québec, Port of Montréal)

For 2001-2002, the POL plan included 12 individual projects and 10 projects in 2002-2003. In 2002-2003, POL 2.2.4 was in its third year of the 3-year established POL Plan. A new 4-year POL Plan takes effect in 2003/2004. EC is leading 1 of these projects in 2002-2003.

The total 2001-2002 annual budget for POL 2.2.4 was $8,955,500 and $4,250,500 for 2002-2003. The total PERD resources available for 2001-2002 were $2,125,000 and for 2002-2003, $1,910,000. PERD funds were divided amongst the departments involved in this POL (see Table 9). For this POL, the leverage quotient of total resources to PERD resources for 2001-2002 was 4.2 and 2.2 for 2002-2003.

Table 9. Percentage of PERD Funds for POL 2.2.4 Allocated to Each Department

Department	Percentage of Funds (%)	
	2001–2002	2002–2003
TC	39.6	63.2
EC, DFO, NRC	32.3	—
EC, NRC, CCG	—	20.9
DFO	26.2	11.7
NRCan	1.6	3.3
POL Management (TC)	0.3	0.9

Environment Canada Projects for POL 2.2.4

Profiles by Strategic Intent
Transportation Sector
Energy Efficiency of Transportation Systems
St. Lawrence Routing Management Support Model

The St Lawrence Routing Management Support Model

Project Manager: Normand Michaud

This project is a follow up on 2 separate PERD projects titled *Ice Forecast in the St Lawrence System* by DFO and *Improving Vessel Routing Methodologies in the St Lawrence system* by EC: With the PERD re-organization toward POL programs, the projects were seen as ideal projects in terms of energy efficiency in the marine transportation system and were combined into one big project called *The St Lawrence routing management support model.* The Laurentian division of Canadian Coast Guard, responsible for safe and efficient navigation in the system, joined as a full partner and agreed to setting up a working prototype in their operational area. In addition, the prototype may also be ran from any commercial PC currently found on the market.

This project is a joint project with DFO Sciences of Laurentian region and with the DFO Canadian Coast Guard operations of the Laurentian region. Partners will include the CCG Operations Centre, CCG Marine Communications and Traffic Services, DFO Science Maurice-Lamontagne Institute, the Canadian Hydraulics Centre of the National Research Council, Transport Quebec, Environment Canada's Marine Services and the Canadian marine shipping industry represented through the Canadian Marine Advisory Committee.

The PERD context is energy efficiency. This R&D initiative aims at determining optimal navigation routes in terms of fuel consumption and GHG reductions. As a sub-benefit, another context of PERD also fits in the project: sustainable development through efficient transportation system

This project benefits EC by:

- Reducing Greenhouse Gas (GHG): The St Lawrence transportation system produces about 2,7 MT of CO2 annually. A 5 to 10% reduction may lead to about.3MT. (regional yearly savings estimated at: 52,000 ton fuel and 200,000 ton GHG). Reductions at country scale will give about 3.6 MT.
- Preventing water pollution due to oil spills or other chemical released at sea during accidents: the routing model will provide the optimal route in terms of fuel consumption, and will also provide alternate routes on request. Severity conditions along the route will be provided, what will make for safer transits.
- Improving the capability to predict environmental information in the 0 to 48 hours range. (the meteorological service of canada, a division of ec, is responsible to provide marine weather warnings to the marine community)

Methodology

The system will apply various technologies to integrate actual weather, tidal, current, ice, water depth, wave and ship performance data to provide routing forecasts for transmission to and subsequent use by domestic and international ships. Trials and field experiments are carried on a regular basis using commercial ships operating on a regular basis in the

Profiles by Strategic Intent

Transportation Sector

Energy Efficiency of Transportation Systems

St. Lawrence Routing Management Support Model

St Lawrence system. Power used by the ship, fuel consumption data, observational data on winds, waves, sea state, water temperature and ice are collected on a regular basis, analyzed, assimilated and fed into the oceanic model. The prototype uses the results to provide fuel consumption and transit times for different classes of ships. Other severity indexes are also derivable from the algorithm outputs. The Canadian Coast Guard with funding and support from the stakeholders involved is currently implementing this prototype system.

Goals, Outputs and Project Success Story

A priority was given for the development of the algorithm to calculate fuel consumption and CO_2 emissions for one class of ship and was realized on target in March 2003. In parallel, an evaluation of the observation of ice feeding the ice model as well as the representation of ice within the model is on target. The monitoring of sea surface temperature and salinity as well as the daily forecast of sea surface temperature, currents, and sea ice has been made available to the partners of the project as well as to the general public, this year, and on the WEB.

This part completes the Phase 1 of the project which covered two fiscal years: 2001-02 and 2002-03. Ice transit performance algorithms have been developed during the last 2 years using the MV Cicero and a prototype has been setup in 2003. The prototype is now running smoothly. It shows that a fuel saving of 9.74% on average is predicted using the algorithms. In a normal winter, this is equivalent to at least 25,000 tons reduction in CO2 for the St Lawrence system.

Funding

The average resources allocated for this project per fiscal year were $223,000 (2001-2002; 2002-2003). An average 67.3% of these resources came from PERD funds, the rest came from other sources (industry, others). The average leverage quotient of total resources to PERD resources for the project was 1.5.

Strategic Intent 3—Buildings and Communities Sector

Strategic Intent 3 is to reduce the overall energy intensity of Canada's buildings and community systems and, consequently, their associated GHG emissions while, at the same time, providing Canadian companies with potential economic opportunities.

Strategic Intent 3 · Strategic Direction 2

Strategic Direction 2 is to provide S&T to integrate energy services (supply and end use) in communities to reduce overall energy requirements, optimize the use of available resources, and reduce environmental impacts including GHG emissions.

Strategic Intent 3 · Strategic Direction 2 · Objective 3.2.4

To develop technical and decision-making process innovations that will help achieve integrated energy management at the community level and contribute to sustainable community development.

POL 3.2.1—Energy Management for Sustainable Communities
Canadian communities are among the most energy-intensive in the world. At the household level, Canadians consume more energy (e.g., for heating and cooling) than almost any other nation in the world and transport-related energy consumption is second only to that of the US. The energy infrastructure serving Canadian communities is organized at national or provincial scales (large generating units dependent largely on non-renewable and distant energy sources); this puts an economic strain on Canadian communities and makes them vulnerable to energy disruption.

This POL focuses on community energy management (CEM) with the goal of reducing the energy intensity of Canadian communities and shifting to more efficient and environmentally-benign community energy technologies. This includes, the use of more efficient community energy distribution systems, and the planning and design of communities and community sub-systems (e.g., transportation, waste management) to minimize energy use exploration of methods with which to supply communities using local sources of renewable or waste energy. An interesting EC project dealing with this aspect of the POL is a novel method of heating a community in Alberta: an aquifer storage based heating system that draws its energy from solar panels. Individual homes in the subdivision will be connected to a district heating system. This district heating system will draw the energy from the aquifer as well as transport the energy from the solar panels to the aquifer. There has also been considerable development in the use of microturbines using LFG as a more efficient and low cost power generation technology. The City of Calgary has agreed to continue using a microturbine at one of their waste facilities. Novel equipment powered by the microturbine waste heat has been installed to remove siloxanes from the land fill gas. This project has great potential at other waste facilities. An EC project that reduces energy demand and fosters sustainable energy and distribution in communities is now evaluating the potential of using green roofs, vertical gardens and urban forestry to reduce residential summer energy consumption through reductions in canopy-level temperatures and shading.

This effort to reduce energy demands on urban centers is sure to attract participation and interest within members of the community.

The following activities are included under POL 3.2.4:

- Community Energy and Waste Technology Development: To deliver the knowledge and tools that will allow the construction, operation and management of energy from thermal networks and waste facilities.
- Community Decision-Making Processes and Tools: To foster community decision-making practices that reduce energy demand and facilitate the incorporation of sustainable energy and distribution supply options into community sub-systems.

The international collaboration in this POL has been achieved with different Implementing Agreements (IA) of the International Energy Agency (IEA), such as energy storage, district heating and cooling including the use of CHP, and process integration.

Funding and collaborative partners include federal departments such as NRCan, EC, PWGSC and CMHC. Other partners include the Corporation Supporting Recyling, Environment Plastics and Industry Council, Dal-Tech, Nova Scotia Agricultural College, the Clean Air Partnership, etc.

For 2002-2003, the POL plan included 18 projects. POL 3.4.2 forms the integration of POLs 3.2.1 and 3.2.3. 2002-2003 has been a year of formulating the new POL plan. EC is leading or participating in 7 of the projects.

The total 2001-2002 annual budget for POL 3.2.4 was unavailable since the POL was formed in 2002. The total 2002-2003 annual budget for POL 3.2.4 was $2,000,000. For 2002-2003, total PERD resources available were $938,000 ($957,000 was the latest figure but the breakdown within departments was unavailable; the former figure was used to prepare the table below). PERD funds were divided amongst the departments involved in this POL (see Table 10). For this POL, the leverage quotient of total resources to PERD resources for 2002-2003 was 2.1.

Table 10. Percentage of PERD Funds for POL 3.2.4 Allocated to Each Department

Department	Percentage of Funds (%)	
	2001–2002	2002–2003
NRCan	N/a	55.8
EC	N/a	37.5
CMHC	N/a	3.5
PWGSC	N/a	3.2

Environment Canada Projects for POL 3.2.4

Design of More Effective Energy Storage Systems

Project Manager: Franck Cruickshanks

Project Objectives

The project is involved, through national and international collaborations, at developing a variety of tools and procedures for implementing Underground Thermal Energy Storage (UTES)- an advanced form of ground-source heat pumping in Canada. The objective of this project is to deliver the knowledge and tools that will allow the construction, operation and management of energy from thermal networks. The interconnections will facilitate higher overall efficiency of the community energy system, as well as the increased use of renewable and local energy sources. PERD funding for this project is to start in 2003-2004.

This project benefits EC since it will strive to integrate energy services in communities to reduce overall energy requirements, optimize the use of available resources and reduce environmental impacts, including air pollution and GHG emissions. This project represents an innovating process that will help achieve integrated energy management at the community level and contribute to sustainable community development.

Methodology

The research involved the development of tools and procedures fro implementing UTES in Canada by:

- Computer models for designing UTES systems;
- Environmental Impact Assessment procedures;
- CSA-Design Standard for UTES;
- In-Situ (borehole) Thermal Response Test (TRT);
- Demonstration Projects.

The area of focus is energy storage as it relates to distributed generation, aquifer thermal energy storage, borehole thermal energy storage, cavern thermal energy storage, land based snow storage for commercial and industrial applications. Cold is also used from the natural environment such as lakes, seawater/harbour waters, ambient cold air in winter, etc. for cooling of community buildings

The design of more effective storage systems was much advanced with the development of the Okotoks, AB project. Plans have been made to build a subdivision in this community with heat from solar collectors, where the solar heat is augmented with thermal energy from aquifer storage. The aquifer will be replenished with energy in the summertime, using the same solar collectors. Besides aquifer storage, solar energy, district heating and advanced home heating systems will be part of this project.

Profiles by Strategic Intent

Buildings and Communities Sector

Technical and Decision-Making Process Innovations

Effective Energy Storage Systems

Goals, Outputs and Project Success Story

Goals for this project include:

- Evaluation of one large building for harbour cooling with underground seasonal cold storage (HRM) (2003-2004);
- Site evaluation and drilling tests in Okotoks, AB for large scale solar district heating system utilizing seasonal UTES (aquifer or borehole) (2003-2003);
- Workshops with European and North American experts on borehole and aquifer modeling, building simulation, and solar collector roof integration (2003-2004);
- Completion of detailed engineering design for Okotoks system (2003-2004);
- Construction of Okotoks system and installation of monitoring equipment (2004-2005)

All initial hydrogeological evaluations are now completed and the project is on target.

Funding

N/A

Profiles by Strategic Intent

Buildings and Communities Sector

Technical and Decision-Making Process Innovations

Energy From Waste Technologies

Development of energy from waste technologies and other alternative technologies:

- ***Microturbines Development/Emission Research from Landfill Gas***

Improvement of Waste Management Decision-Making::

- ***Integrated Waste Management (IWM) Model***
- ***Advanced Landfill Technology***

Project Managers: Dennis Jackson and Alain David

Projects' Objectives

The three projects Microturbines Development/Emission Research from Landfill Gas, Integrated Waste Management (IWM) Model, and Advanced Landfill Technology do not stem from a previous PERD project. Environment Canada, NRC and the City of Calgary are working in partnership to demonstrate microturbine technology for energy production, and employ gas cleaning technology. Environment Canada, the University of Waterloo, Environment Plastic Industry Council (EPIC), and Corporations Supporting Recycling (CSR) are working in joint venture to update and expend the IWM Model.

Specific objectives for the 3 projects are the following:

1) Mircroturbines Development/ Emission Research from Landfill Gas
To demonstrate microturbine technology for energy production. Enhanced testing from landfill gas and emissions from combustion sources will be undertaken to demonstrate benefits of clean combustion. Landfill gas testing will be focused on components of the gas which can cause complications in reciprocating engines and microturbines. Previously funded activities through PERD has attracted attention and funds to perform additional research from the CCAF 2000. PERD funds will augment the CCAF research funds and will be used towards additional research and demonstration for microturbine use, development, and marketing opportunities in Canada.

2) Integrated Waste Management (IWM) Model
The IWM Model provides the ability to compare environmental impacts from a variety of waste management systems options. Further, it allows for the determination of energy requirements and GHG emissions associated with the various waste management systems. The IWM Model requires constant updates on energy data.

3) Advanced Landfill Technology
Advance and demonstrate the concept of bioreactors for optimized energy recovery. This new landfill technology has the potential to stabilize wastes more quickly, increase the generation of landfill gas to optimize energy production, reduce GHG emissions, and provide a more controlled environment for potential environmental impacts.

With the ratification of the Kyoto Protocol, the Government of Canada has made climate change a national priority. EC has a lead position in developing initiatives that support Canada's commitments to reduce GHG emissions and help it adapt to the impacts of climate change.

These projects are important as they advance the development of alternative energy systems for sustainable development. Additional benefits include the enhancement of sustainable waste management strategies, and the reduction of GHG emissions from the destruction of methane and from the offset of fossil fuel use.

These projects complement the PERD program by reducing energy consumption, increasing renewable energy development , and therefore reducing CO_2 emissions from waste energy.

Methodology
Specific methodologies for the 3 projects are the following:

1) Microturbines Development / Emission Research from Landfill Gas
The portable power system, set up at the Shepard Landfill in Calgary (AB), included an LFG processing and conditioning system and a Capstone 330 (30 kW nominal output) microturbine. Operational parameters considered and monitored during the pilot testing included:
    - Microturbine: electrical power output, power import requirement, system stability, parasitic load, voltage, amperage, rpm, operating hours, total kWh and exhaust emissions;
    - Landfill gas: inlet and outlet gas conditions for the fuel processing system, including gas composition (CH_4, CO_2, N_2, O_2), flow rate, pressures, temperatures, trace contaminants (siloxanes, H_2S, VOCs, etc.); and
    - Other parameters: turbine efficiency, online availability, turndown ratio, heating value range of operation, fuel gas pressure range, and fuel gas temperature range.

2) Integrated Waste Management (IWM) Model
The IWM Model considers the full range of waste streams to be managed and views the available waste management practices as a menu of options from which waste managers can select the preferred option based on site specific environmental, economic and social considerations.

The model development and updating included:
- Completion of needs assessment;
- Research and integration of the Canadian Raw Material Database against other sources;
- Update and expand to include energy from manufacturing, pre-combustion andfabrication stages; and
- Completion of additional modules.

3) Advanced Landfill Technology
The system boundaries included not only the landfill cell construction operation and associated emissions, but also the production processes and transport necessary to the implementation of these technologies. System boundaries were also expanded to include electricity and heat production processes to take into consideration the energy recovered from the collected landfill gas.

Technological developments include three design components and one operational requirement that strive to enhance anaerobic methanogenic biodegradation to stabilize degradable matter:

- Enhanced Containment System for the containment, control and collection of leachate;
- Leachate Collection and Recirculation System consisting of leachate collection pipes in the bottom drain layer, sumps and pumps to collect and convey the moisture up into leachate recirculation pipes in horizontal terraces or into vertical recirculation wells;
- Gas Collection and Extraction System with active extraction of landfill gas through horizontal or vertical wells; and
- Active Operation and Monitoring, i.e., active controlled leachate recirculation, gas extraction and enhanced monitoring with the goal of rapid biodegradation.

Goals, Outputs and Projects' Success Stories
Specific goals and outputs for the 3 projects are the following:

1) Microturbines Development / Emission Research from Landfill Gas
Output: Report on testing and demonstration of more efficient and low cost power generation and technologies using LFG.
Goal and Performance Indicators:

- Two systems installed and tested
- Two commercial orders for new technology
- Gas cleaning technology successfully employed

Status: The gas cleaning technology is being installed at the microturbine unit in Calgary. The unit will remain in Calgary for the foreseeable future. An Agreement with the City is in place. The City is interested in long term power research and development energy opportunities. Gas cleaning technology will be conducted early in 2004.

2) Integrated Waste Management (IWM) Model
Output: Update and expended IWM Model on new platform.
Goal and Performance Indicators:

- Model and new modules updated.
- Most large municipalities representing 25% of the population using the model.
- Needs assessment and consultations completed.

Status: Energy data is being revised and updated. Additional research is required for the integration of the Canadian Raw Materials Database into the model. The model needs assessment was completed in the fall of 2003.

3) Advanced Landfill Technology
Output: Diagnostic process to assess advanced landfill technology using a life cycle approach.

Goal and Performance Indicators:

- Process completed;
- Most of the largest communities and private sector companies considering advanced technologies and using the tool.

Status: Energy evaluation of life cycle has been completed. Integration of the information is to be accomplished. Additional research is required on some energy impacts since time constraints have not allowed for all studies to be completed.

Specific success stories for the 3 projects include the following:

1) Microturbines Development / Emission Research from Landfill Gas
The testing of a Capstone 30 kW microturbine is on-going at the Shepard landfill site, Calgary (AB). As of May 2002, the unit has operated for 1,555 hours and produced a total of 38,800 kWh of total electrical power. Moisture and siloxane removal systems are vital to the long-term operation of the microturbine and will be reported in the future. Excessive wear (on injectors and turbine blades) and microturbine failures resulting from siloxanes have been documented by Capstone.

2) Integrated Waste Management (IWM) Model
The model has been used increasingly to evaluate energy impacts of waste management. Several requests from large municipalities have been made to integrate energy data from advance thermal treatment.

3) Advanced Landfill Technology
The bioreactor represents an improvement in typical engineered landfill processes since energy is recovered from the collected landfill gas and this reduces the need for external energy, and landfill gas is produced at a greater rate, reducing the amount directly released to the atmosphere after the end of the post-closure monitoring period. The engineered landfill requires more materials; energy inputs via the nonroad equipment used and supplemented energy from external processes to achieve the same performance as the bioreactor landfill. The raw material inputs, solid waste outputs and emissions associated potential environmental impacts are also greater for the engineered landfill option. From these results, the bioreactor landfill can be identified as the preferred option from an energy and environmental point of view.

Funding

The average resources allocated for this project per fiscal year were $359,500 (2001-2002; 2002-2003). An average 48.5% of these resources came from PERD funds, the rest came from other sources (industry and others). The average leverage quotient of total resources to PERD resources for the project was 2.1.

Integrating Urban Forestry, Green Roofs and Vertical Gardens to Reduce Energy Consumption

Project Manager: Brad Bass

Project Objectives

The project is part of a larger research effort to assess the impact of building surfaces on urban temperatures and stormwater runoff and strategies to adapt to climate change by modifying these surfaces. The research will evaluate the potential of using green roofs, vertical gardens and urban forestry to reduce residential summer energy consumption through reductions in canopy-level temperatures and shading.

This project benefits EC since it will build on previous research, but at a different scale. The work raises EC's profile with municipalities, USAID and PERD. The project is building new partnerships with academia and other agencies. It is developing new results for publication to raise profile of EC research in academic community.

Methodology

In order to attain its objectives, the project will:

- Collect landuse data;
- Run baseline scenarios using the USAID urban forestry model, UFORE (an empirical model that simulates energy conservation and air quality due to urban vegetation);
- Identify buildings in study area suitable for roof and wall modification with vegetation, and;
- Run UFORE scenarios with varying amounts of vegetation.
-

Goals, Outputs and Project Success Story

The project is in its first stages of research but has already land use data has already been collected. GIS database has been created and various scenario inputs for UFORE have been prepared.

Since the project is in its early beginnings, it is still too early to report success stories. However, there is a high degree of interest among target groups as measured by the number of individuals requesting copies of produced reports on linkage between neighborhood design and travel behavior, neighborhood design energy supply options, and energy implications of green roofs.

Funding

The average resources allocated for this project per fiscal year were $85,000 2002-2003 only). An average 29.4% of these resources came from PERD funds, the rest came from other sources (A-Base and others). The average leverage quotient of total resources to PERD resources for the project was 3.4.

Clean Air Portal

Project Manager: Franck Portalupi

Project Objectives
This project builds on the past municipal research by FCM, and POL 3.2.3 (Review of Municipal Clean Air Strategies, and Achieving Energy Efficiency through Integration of Land-Use and Transportation Planning in Canadian Metropolitan Regions), and extends the National Climate Change Process - Municipalities Table work.

Thus with the knowledge of this previous research, Clean Air OnLine has gone on to research two areas in more detail:

- "Tools to support municipal decision making in climate change and clean air", and;
- "Reducing air emission and energy use through integrated community planning: and examination of current practices in the GTA".

In addition, all research from 2004 and past POL projects have contributed heavily to content, structural design and linkages of the Clean Air OnLine websites- both national and GTA pilot.

As part of the *Energy Management for Sustainable Communities (POL 3.2.4)*, the Clean Air OnLine Pilot Project contributes to the Government of Canada's effort to reduce climate change and improve air quality at the community level. Clean Air OnLine can be used as a supporting element in the new deal for cities and communities by:

- Providing options for municipal energy or air emission software tools, and;
- Contributing to the creation of an on-line resource for municipal decision makers, citizens and local community groups.

The focus of the Clean Air OnLine Pilot project will be on developing new and innovative ways to use existing web-based tools and identifying additional tools required to support community action. Community partners will play a key role in defining project priorities and testing and refining the system. The Pilot will increase understanding of how web-based information systems can be enhanced and adapted to provide interactive and individualized support to mobilize community action. Documenting the process of setting up this expert system will advance understanding within the R & D community of how web-based tools can advance community-level action, which can facilitate future projects in other regions of Canada and else where in the world.

The Clean Air OnLine objectives, in the context of PERD, include:

- Involving key local players to ensure relevance of expert system to the user;

- Reduction of harmful air emissions by encouraging individual and communities level actions in the GTA (and through the Web in all of Canada) by developing a clean air & climate change expert and interactive information system. The system will provide relevant information on energy choices affecting air emissions, suggest ways to reduce these emissions and connect to key actors and initiatives in the Greater Toronto Area;
- Working with committed community partners, develop and test a prototype Web based expert information system to support local actions that can significantly reduce emissions causing both air pollution and climate change;
- Conducting supportive research for municipalities and communities (i.e. Partners for Climate Protection).

In addition, CAOL provides a common platform from which research that is consistent with the stated PERD R&D Strategies and may be funded by PERD can increase the ongoing profile and accessibility of their work.

This project benefits EC since Environment Canada works toward reducing the health and safety impacts of environmental threats. It is critical that the public have easily accessible, accurate and relevant information on Clean Air. Clean Air OnLine is a format where Environment Canada can inform Canadians about the issue of Clean Air in a manner that is

- Clear and concise
- Easily accessible and up-to-date (on the Internet)
- Geographically relevant
- Relevant to people's day-to-day lives
- Demonstrative of the inter-related work of Environment Canada

CAOL also facilitates and encourages information awareness and exchange throughout EC

Methodology

We are working with interested representatives from the Canadian government and academic communities, along with our key partners for the project, to document the overall process of this information system in order to facilitate similar experiences in other regions of Canada and else where in the world. Each phase of the project will rely on a different methodological approach.

Phase 1- Background Research:
This phase focused on creating a solid information base through advisory committees, needs assessments, and research of currently available information, tools and resources.

Phase 2- Prototype:
Based on findings of phase I, this phase will focus on developing a prototype web information system that provides easy access to existing information; researching and developing content; creating new tools identified in the needs assessment; and, working with

the owner of existing relevant information and tools in order to adapt their information to better serve the needs identified as part of this project.

Phase 3-
Upon successful completion of phase II, the project will move to pilot and assess the web information system with multiple communities and groups; and organize a workshop to discuss results and will explore the feasibility of expanding the initiative into other regions of Canada.

Goals, Outputs and Project Success Story
Timeline:
The Clean Air OnLine Pilot Project has just completed Phase I (as outlined in the initial proposal). As part of this Phase, the project has completed the following items:

- Created an advisory committee formed of key community decision makers (including the Greater Toronto Area Clean Air Council) to help identify needs of the information system;
- Conducted a formal needs assessment using focus group and other relevant approaches;
- Researched currently available information, tools and resources that could be included in the proposed information system;
- Researched best practices with regard to the use of Web based information systems to encourage individual and community level actions.

Project Outputs:
As Phase I was focused on assessment and information gathering, a Needs Assessment Report (Output 1) was completed. This report builds on building on existing work done by local groups and identifying gaps / new research areas (Greater Toronto Area, Clean Air Council, Toronto Atmospheric Fund).

As the project moves into Phase II, the prototypes of the Clean Air OnLine websites are being developed (Output 2). These prototypes will allow testing of this expert system with individual citizen and local community group (community meetings) (Output 4).

Status of the Project:
The project is progressing on schedule, with the completion of Phase I and the implementation of Phase II expected for Year 2 and 3.

Clean Air Online will move away from information organized by government silos and encourage the sharing of information, ideas and resources among those whom are involved in air quality issues. This information sharing can be seen in the partnership between the national and local scales, the effective linkages with climate change and energy information, and in the interactive portal website structure. More importantly, this move away silos is seen in how each page emphasizes the topic of clean air and air quality, and not governmental departments or organizations. This is an important feature of Clean Air OnLine and greatly improves its value as a place to explore air quality issues.

The Clean Air OnLine website strives to provide more than an overview and introductory context to the issue of clean air. It also focuses on exploring what community planning tools are available and how they can be designed to assist communities in making energy efficient decisions.

Clean Air OnLine takes advantage of innovations in website design and content management systems. In its creation, Clean Air OnLine had to overcome two main technical challenges:

- Integrating and/or coordinating information currently owned and managed by many different federal and non-federal partners; and,
- Providing an effective and efficient way to create, upload and manage information posted

Many Clean Air OnLine partners already have and manage extensive databases of air quality related information. Not all of these databases use the same computer file format, many require different computer platforms to operate, and most are stored in different locations. Since it is not possible, desirable or necessary to combine all of the data into a single location, this data needs to be combined dynamically and seamlessly.

Clean Air OnLine partners have either provided actual information or have allowed access to their databases for use on this website. The content management system has been to coordinate information from these sources and package it into a single website. To insure content integrity the information is still owned and maintained by those who developed it.

Clean Air OnLine concept has generated much interest due to its multi-tiered partnership and stakeholders (public, private, non-governmental); and organization of information based on the general public's perception of the topic (Clean Air). This interest is resulting in interest from many new partners and stakeholders, and an interest from other municipalities.

Funding

The average resources allocated for this project per fiscal year were $378,000 (2002-2003). An average 29.1% of these resources came from PERD funds, the rest came from other sources (A-Base and others such as Border Initiative, Sustainable Communities Energy Initiative (SCEI). The average leverage quotient of total resources to PERD resources for the project was 3.4.

Strategic Intent 4—Industry Sector

Strategic Intent 4 is to reduce the overall energy intensity of Canada's industrial sectors and, consequently, their associated GHG emissions while, at the same time, improving productivity and providing Canadian companies with potential economic opportunities.

Strategic Intent 4 ·Strategic Direction 3

Strategic Direction 3 is to provide S&T to advance generic energy-related technologies and processes to reduce energy intensity, particularly in industry, to achieve productivity gains and reduce GHG emissions and other wastes.

Strategic Intent 4 ·Strategic Direction 3 ·Objective 4.3.3

The Development of Advanced Technologies and Products for Heat Management and Separation Including High Efficiency Drying.

POL 4.3.3—Research, Development and Deployment for Industrial Separation and Refrigeration (SEPREF)

The SEPREF POL (Industrial Separation and Refrigeration) focuses on decreasing the energy intensity and improving the productivity of selected industrial unit operations that are widely used, are energy-intensive and are amenable to a wiser use of energy through knowledge and technology. The SEPREF POL aims at generating energy-related knowledge and technologies that can be deployed to help Canada meet its environmental stewardship commitments, including the reduction of greenhouse gas emissions; to formulate sound energy policies; to enhance national capacity for energy technology innovation; and for energy-related industrial development for both the public and private good.

New eco-efficient processes that demand less energy and produce less harmful emissions are marketable commodities. They may aid many countries in reaching their environmental commitments and so offer an economic opportunity to Canadian developers. One such EC project (PERD funded) in this POL "Applications of Microwave-Assisted Process (MAPTM) to Solvent-less Synthesis and to Low Solvent, Energy-Efficient Extraction" lead to the development of a new process that uses only 10% of the energy required by the one it will replace. This ingenious process has already found commercial application and is expected to result in savings in the pharmaceutical and chemical preparation sector.

The following activities are included under POL 4.3.3:

- Drying Technologies
- Flow-reversal reactor technology
- Membrane separation technology
- Microwave-assisted technology
- Heat (cold) management technology

SEPREF is a "Multi-Player" program to be delivered jointly by Natural Resources Canada, the National Research Council and Environment Canada in partnership with numerous industrial players (e.g. Enbridge, Consumers Gas Parrheim Food inc., Forintek, Westmorland Fisheries, etc.), universities (e.g. Université Laval, McGill University, École Polytechnique, Concordia University, University of Alberta, Tianjin University, Université de Monction, etc.), various associations (e.g. Agence de l'efficacité énergétique du Québec, Association des manufacturiers du bois d'œuvre du Québec) and international partners (e.g. Chinese Research Academy of Environmental Sciences, SAIREM s.a. (France), EPA (US), CSIRO (Australia).

For 2001-2002, the POL plan included 5 major projects and 4 major projects in 2002-2003. In 2002-2003, POL 4.3.3 was in its third year of a 4-year established POL plan. EC is leading 1 of these major projects in 2002-2003.

The total 2001-2002 annual budget for POL 4.3.3 was $2,441,000 and $3,179,000 for 2002-2003. The total PERD resources available for 2001-2002 were $1,064,000 and for 2002-2003, $1,064,000. PERD funds were divided amongst the departments involved in this POL (see Table 11). For this POL, the leverage quotient of total resources to PERD resources for 2001-2002 was 2.3 and 3.0 for 2002-2003.

Table 11. Percentage of PERD Funds for POL 4.3.3 Allocated to Each Department

Department	Percentage of Funds (%)	
	2001–2002	2002–2003
NRCan	66.5	66.5
NRC	25.9	8.5
EC	7.5	7.5
Unallocated	—	17.5

Environment Canada Projects for POL 4.3.3

Applications of Microwave-Assisted Processes (MAP^{TM}) To Solvent-less Synthesis and to Low Solvent, Energy-Efficient Extraction

Project Manager: Jocelyn Paré

Project Objectives

This project stems from the PERD "extraction" project (1997–2000). The project has been broadened widely as a result of our successful application for a TEAM-funded project involving CanAmera Foods and BC Research. While this latter project deals exclusively with the extraction component of our "sustainable chemistry" program, its magnitude and demand on personnel resources are such that the synthesis component has been impacted significantly. For example, the TEAM project funded adequately the extraction work, hence allowing the MAP Division to invest more heavily into the synthesis-related activities.

The objectives of the project are to provide Canada's synthesis and extraction industrial sector with low solvent and low energy consuming processes that will offer health, economic and environmental benefits both nationally and globally while supporting sustainable development and reducing toxic substances and GHGs. This project aims to further the development of the Government of Canada's patented Microwave-Assisted Processes (MAP) and to further the development of the use of microwave–assisted synthesis as an energy-efficient environmentally friendly industrial process for the synthesis industry.

An objective of this project is to further the development of the use of microwave-assisted synthesis as an energy-efficient environmentally-friendly industrial process for the pharmaceutical synthesis industry. This is in agreement with PERD's main objective "to provide the science and technology necessary for Canada to move toward a sustainable energy future". It addresses many of EC's business lines of "giving Canadians the tools to build a greener society" … "by ensuring that economic development is environmentally sensitive …", "… pollution prevention… greenhouse gases reduction, …" . Furthermore, it conforms to Health Canada's mandate to improve public health and safety.

These activities benefit EC because they fall in the industrial demonstration of pollution prevention work category required under CEPA and are in agreement with EC's business lines, as well as support the government's "good governance" objectives. It also supports EC's duty under the Fisheries Act by providing means to reduce or eliminate toxics release into wastewater effluents. The research also addresses government priorities, including:

Job Creation, Wealth Generation, and Competitiveness

This project will provide cleaner, low-solvent or zero-solvent, more cost and energy–efficient extraction and chemical synthesis processes that will enhance the international competitiveness of the Canadian food and chemical sectors (thus, create or protect jobs in Canada), while providing increased market opportunities. There also is significant potential to further provide opportunities for yet new, unprotected applications of the use of microwaves in other industrial processing activities where selective heating would apply and further reduce overall energy consumption. To date, the licensing of the technology has already resulted in sales of hundreds of analytical systems and the creation of jobs while providing for more environmentally sustainable ways of conducting economically sound business.

Environmental Improvement
Comparative laboratory work has shown that MAP uses significantly less solvent (*i.e.*, less toxics) than conventional processing technologies. Also, microwave–assisted synthesis generates fewer solvent wastes and consumes less energy; thereby, helping reduce emissions of greenhouse gases and other pollutants from energy production.

Advancement of Knowledge
The use of microwaves to enhance biological, chemical, and physical processes is inherently innovative. Microwave–assisted synthesis is under accelerated development as evidenced in the increasing number of reports dealing with MAP and by the numerous patents granted in this area over the past few years. The expertise and experience of the team involved in this project is unique world–wide, and could provide Canada with an edge in the relatively unexplored area of novel atmospheric–pressure, solvent–less, microwave–assisted organic synthesis procedures.

Methodology
The major deliverables are being achieved through laboratory studies and bench–scale tests carried out at the Environmental Technology Centre (Ottawa) and at the Wastewater Technology Centre (Burlington), Environment Canada.

MAP, inherently, is an innovative process as evidenced by the granting of Patents in each and every jurisdiction around the world where an application was filed. Conventional methods for extraction of edible oils from plant material make use of very large volumes of hot hexane requiring enormous amounts of energy. Hexane is relatively transparent to microwave irradiation and is well-suited for the MAP technology. MAP is based upon the selective and localised heating of residual moisture in plant materials, requiring basically no energy to heat the solvent and the extraction apparatus. The increase in pressure resulting from the phase transition (expansion of liquid into gas) of this residual water causes the disruption of the physical structure of the plant materials thus releasing the contents into the surrounding, relatively cold solvent which dissolves it. This mechanism also implies that less solvent is required, thus an indirect benefit in energy savings since significant amounts of energy are required to manufacture food-quality hexane (over 6M tonnes of hexane are used each year in Canada by the food industry). It also represents a direct benefit in terms of reducing GHG emissions by requiring less energy to remove the solvent from the oil and by distilling it back to food-grade specifications. Obviously, less waste is produced than conventional industrial processes, thus bringing additional environmental benefits as well as economic benefits (by reducing costs associated with waste management). The spent plant material can be either composted or used in livestock feed formulations. In other applications dealing with high value-added materials, the process also allowed for the substitution of more toxic and more expensive solvents. Substituting liquefied propane or butane for hexane would bring in additional benefits; little, if any, energy would be required to remove the solvent from the edible oil and losses during the various processing stages would be reduced accordingly. Low pressure liquefied gases extraction is not practised currently due to the generally limited diffusion of liquefied gases into plant material, a parameter of no importance in MAP.

Solvent-Less Synthesis

Statistics show that in 1993 the pharmaceutical industry in Canada was made up of 122 manufacturing establishments. This represented more than $4.3 billion in shipments. "Total factory-gate sales (shipments from Canadian manufacturers plus imports minus exports) of medicines in Canada were $5.4 billion, of which patented products accounted for 44%" (Scrip's 1995 Yearbook, Volume II, Part V: Countries). The energy requirement associated with the production of pharmaceutical products is relatively high compared to other synthetic products. In fact, the traditional "wet" synthesis requires large amounts of energy to carry out relatively inefficient chemical reactions. This high energy use can also be related to the high solvent use. In fact, heating processes associated with effecting chemical reactions involve the random application of thermal heat to the solvent-reactants mixture. Solvent-less procedures are impractical under convection heating conditions. The latter is not true under microwave heating conditions where selective heating can be applied to achieve the required synthetic goals. The energy involved in purifying and desolventizing steps are truly unique given the high purity and quality control parameters associated with pharmaceutical products and contribute enormously to compounding the energy demand. In fact, with the exception of cement making one could argue that the energy to mass ratio used in this synthesis industry might be the highest of all other industrial manufacturing processes. Hence, combining the use of solvent-less conditions and energy-efficient use of microwaves offers a broad potential in terms of environmental gains, health and economic benefits, and innovation.

Goals, Outputs and Project Success Story

The goals of this project are:

- To further the development of Environment Canada's energy-efficient patented Microwave-Assisted Processes (MAP™)[1] for the synthesis industry in Canada, and:
- To provide the Canadian pharmaceutical industry with a unique energy-efficient industrial process that will offer health, economic and environmental benefits that will provide it with international leadership in the field.

Deliverables and Project Successes:

Deliverable 1 (March 2003): Fully characterized procedures for i) a batch microwave-assisted synthesis under atmospheric and solvent-less conditions at the bench-scale; and ii) one selected target to be synthesised under microwave, continuous-flow conditions.

Status: Some of the components of this deliverable were modified in order to improve the response and behaviour of the equipment. New hardware and software were added to the dielectmeters to make them fully automatic and complement our goals. This was followed by a full characterization and validation of these equipments. Results in terms of their precision, accuracy and reproducibility will be presented at the upcoming 39th IUPAC Congress and 86th Conference of the Canadian Society for Chemistry that will take place in Ottawa in August 2003. Work is in continuation in the investigation of the influence of dielectric properties of individual components involved in chemical processes. The apparatus was also modified by interfacing it with a computer controlled FT-IR. This FT-IR uses a flow through cell where microwave-assisted chemical processes are allowed to take place. The goal is to validate MAP technologies as green chemistry tools that are characterized by low energy consumption, low chemical wastes release, and low green house gas emissions. In parallel to this we pursued our microwave-assisted solid-phase synthesis of functionalized polymers and proceeded with batch scale-up of some reactions. These provided good results and are still on-going.

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[1] MAP is a registered Trademark of Her Majesty the Queen in Right of Canada, as represented by the Minister of Environment.

Deliverable 2 (March 2003): A ready-to-be-implemented energy-efficient technology for the Canadian edible oil processing industry based upon low solvent losses, energy-efficient MAP hexane extraction or upon a low volume energy-efficient liquefied gas MAP extraction process.

Status: The project was further extended into FY 02-03 (and will also be for FY 03-04 and 04-05 as new feedstock are being added to the list of viable products). Radient Technologies Inc., a spin-off company of BC Research, was incorporated in June 2002 and established its operational facilities at the Wastewater Technology Centre in Burlington. Under its licence agreement with Environment Canada, Radient became the entity responsible for the operation of all MAP related projects at the pilot-scale level. Also in 2002, CanAmera Foods changed ownership and its new owner has demonstrated a lot of interest in the continuation of the extraction of Canola oil using the MAP family of technologies. These studies are being extended, concentrating on the even greater economic and environmental benefits possible *via* the development of low-pressure liquefied gases as the extraction solvent for edible oils. This approach has proven to be extraordinary for two reasons: 1- it greatly simplifies one of the most energy-intensive steps in the extraction process – solvent removal from the product; 2- it opens the door to the use of solvents that are an alternative to the traditional hexane. This latter point is of great interest to the commodity food oil industry as they seek means for responding to emerging environmental and regulatory pressures surrounding the use of hexane.

One of the great successes of the TEAM project was the successful demonstration of liquefied-gas MAP at the bench scale. The use of liquefied gases such as butane or propane was proposed as parallel work during the project in order to potentially broaden the range of use of the technology. The result was the successful construction and testing of a small bench-scale MAP system designed for batch operation with liquefied butane and the solvent. In addition to enabling the replacement of hexane with a cheaper, non-toxic substitute, liquefied-gas MAP also enables even greater energy reductions and associated GHG emission reductions.

Because of the success resulting in this demonstration project, a consortium led by Radient Technologies Inc. submitted a project application to SDTC and was successful at getting funding for next year. The overall objective of this study will be to design, construct, test and verify a demonstration-scale liquefied-gas MAP extraction plant for edible oils and other more valuable natural product extracts, leading to the completion of detailed engineering cost-benefit analyses for various products.

Fiscal Year 2003-2004

Deliverable 1 (March 2004): To identify novel applications of microwaves in heterogeneous chemical synthesis where the uniqueness of such energy application could demonstrate high potential for significant energy and solvent use reduction. To render the dielectmeter more commercial-ready to ensure that other research groups have access and contribute to this expanding field in other industrial sectors.

Deliverable 2 (March 2004): To further develop an innovative "eco-efficient" platform technology that promotes sustainable development in the new bio-based economy. To further advance Canadian technology by continuing the development, demonstration and commercialisation of other applications of MAP, in particular applications related to the industrial extraction of valuable products from renewable biomass.

Deliverable 3 (New) (March 2004): To design and construct a solid-state based microwave generator for laboratory applications to be used in screening procedures.

Awards granted to members of the MAP Team:

- In major part as a result of this research program, representatives from TPPD, Sairem (France), CanAmera Foods, BC Research, McGill University, the US EPA and ETAD were awarded the 2001 5NR Science Award to Leaders in Sustainable Development.
- In 2001, the FPTT (Federal Partners in Technology Transfer) Innovator Award, for the development and transfer of an innovative Microwave-Assisted Process (MAP™) to extract and remove various components from a host material was awarded to Prof. J. R. Jocelyn Paré, manager of this PERD project.
- For its continued effort in the development and commercialisation of the Microwave-Assisted Processes, the MAP Team was awarded the 2002 Head of Public Service Award in the Excellence in Service Delivery Category for Collaborative Working Relationships.
- In June 2003, Prof. J. R. Jocelyn Paré, was awarded the Professional Institute of the Public Service of Canada Gold Medal Award in the field of pure and applied science, which recognizes the excellence of his research program.
- In December 2003 Prof. J. R. Jocelyn Paré received the Outstanding Achievement Award, the highest expression of recognition under the Government of Canada's Recognition Policy, for his Leadership and Innovative scientific and technological achievements.
- Also in December 2003, Prof. J. R. Jocelyn Paré was honored with the Meritorious Service Medal Award, in recognition of his numerous successful industrial applications resulting from the development of the MAP family of technologies which are used worldwide, and for which Canada holds patent rights around the world.

Funding

The average resources allocated for this project per fiscal year were $1,535,500 (2001-2002; 2002-2003). An average 5.1% of these resources came from PERD funds, the rest came from other sources (A-Base, industry (CanAmera Foods, BC Research) and others such as TEAM). The average leverage quotient of total resources to PERD resources for the project was 19.8.

Strategic Intent 5—Electricity Sector

Strategic Intent 5 is to reduce the environmental impacts of Canada's electricity infrastructure, particularly greenhouse gases, through alternative electric power generation, increased efficiency of fossil-fueled plants, and strategies to capture and manage emissions.

Strategic Intent 5 · Strategic Direction 1

Strategic Direction 1 is to provide S&T to increase the proportion of Canada's electricity supply from renewables and distributed systems which offer improved system integration and reduced environmental impacts. (R&D activities in this area will exclusively address generic technological issues whose applications are not related to communities, buildings, and industry).

Strategic Intent 5 · Strategic Direction 1 · Objective 5.1.1

Improving the Economics and Efficiency of Conversion of Renewable Energy to Electricity Including Related Storage, Hybrid, and Systems Technologies.

POL 5.1.1– Electricity from Renewable Energy Technologies
Canada is a world leader in the production of renewable energy- approximately 17% of its primary energy supply comes from such sustainable sources. Canada's renewable energy is primarily derived from two sources: water (11%) and biomass (6%). Renewable energy sources such as wind power and solar energy, solar thermal and photovoltaics (PV), as well as the newer small hydro and biofuels technologies are rapidly gaining in importance.

This POL focuses on the accelerated development of emerging renewable energy technologies used to generate electricity. It covers the generation of electrical energy from Wind energy, Small Hydro, Biomass, Photovoltaics, and the associated infrastructure issues. By improving the economics and efficiency of renewable energy technologies, Canada can increase its low or non-CO_2 emitting energy supply options to address the Kyoto targets. One target set by the Climate Change Plan for Canada calls for '10% of new electricity generating capacity to come from emerging renewable sources'. Projects such as those undertaken within POL 5.1.1 are expected to play a key role in meeting this target.

Highlights within this POL are numerous and include research by NRCan on new wind-energy systems or components developed /tested, pointing to promising advantages over existing ones and hence potential manufacturing opportunities such as the New Direct Drive Generators for 10-50kW wind turbines allowing more efficient wind-energy conversion. In the biomass to electricity field, several companies are making progress in their efforts to advance bio-oil for electricity generation. An EC project reports a major accomplishment with respect to wind modeling/forecasting. Their modeling technique is important both for the transfer of the wind modeling technology to the wind energy community, and as development of a component of an improved wind forecasting system. A new solar portion of the EC project is aiming to provide spectral irradiance data for the PV industry in anticipation of new ISO standards on PV efficiency. The summer observations of spectral irradiance are some of the first such observations in Canada.

The following activities are included under POL 5.1.1:

- Wind Energy Technology Development
- Small Hydro Technology Development
- Biomass Conversion to Electricity
- Solar PV Electricity Technology
- Infrastructure Support for all renewable energy electricity generating technologies such as resource assessment, interconnection issues, ecological and environmental issues, and geotechnical issues associated with electricity generation/transmission technologies.

International partnerships include the International Energy Agency (IEA) as well as a number of bilateral collaborations with the US and Europe for Bioenergy, PV, Stream Flow Management, Small Hydro, and others.

Funding and collaborative partners include federal departments such as NRCan, EC, DF&O, PWGSC and NRC (IRAP), the Climate Change Action Plan (TEAM) and other related governmental programs. POL 5.1.1 also has a wide range of R&D partners and collaborators from industry (e.g Bolwell Composites Technologies, MSC Entreprises, Dynamotive Energy Systems Corp, Enerkem Technologies, and many more), universities (e.g. Université Laval, École de Technologie Supérieure, University of New Brunswick., Dalhousie University, University of Buffalo, etc.) and other agencies (e.g. International Energy Agency, CSA, Parks Canada, etc.)

For 2001-2002, the POL plan included 10 projects and 11 projects in 2002-2003. POL 5.1.1 is closely linked with POLs 3.2.2 (Renewable Energy in Off-Grid/Remote Communities), 4.3.3. (Forest and Forest Products Industry), 2.1.3 (Transportation Fuels from Renewable Sources) and 5.1.2 (Distributed Generation). EC is leading 2 of the projects.

The total 2001-2002 annual budget for POL 5.1.1 was $15,609,000 and $7,207,000 for 2002-2003. The total PERD resources available for 2001-2002 were $1,182,000 and for 2002-2003, $1,205,000. PERD funds were divided amongst the departments involved in this POL (see Table 12). For this POL, the leverage quotient of total resources to PERD resources for 2001-2002 was 13.2 and 6.0 for 2002-2003.

Table 12 Percentage of PERD Funds for POL 5.1.1 Allocated to Each Department

Department	Percentage of Funds (%)	
	2001–2002	2002–2003
NRCan	84.3	78.7
EC	10.2	9.4
DFO	5.5	7.1
POL Management	—	4.8

Environment Canada Projects for POL 5.1.1

EC Wind and Solar Energy Resource Assessment- Solar Radiation

Project Manager: Bruce McArthur

Project Objectives

The Solar Radiation portion of the present PERD project is new work. The objective of this aspect of the project is to provide spectral irradiance data for the PV industry in anticipation of new ISO standards on PV efficiency. The plan is to provide observations of spectral irradiance at three locations by 04/05 that can be used by PV manufacturers and researchers.

This project benefits EC since the observation of spectral irradiance is necessary not only for PV applications, but for climate, air quality monitoring, agriculture, the retrieval of a variety of parameters from satellites. The funds provided through PERD provide a means of offsetting costs associated with the development of surface-based observations that can be used in the above applications.

Methodology

The first year of the project was to begin developing a prototype instrument for the observations that are to begin late in the second year of the project. The second year will complete the development work and if funding levels are appropriate begin the installation of spectral radiometers at three locations. The final year of the project will be the collection, quality assurance, and provision of data to the PV community. The data will also be of interest to the air quality community and the satellite community.

Goals, Outputs and Project Success Story

In 2003-04 observations were made at the Bratt's Lake Observatory using a scanning radiometer. While not an operational instrument the scans provide information on clear sky spectral irradiance and add to our knowledge base of operating issues that must be resolved before operational measurements can be made.

In 2003-04 the National Atmospheric Radiation Centre completed development of a calibration facility for spectral radiometers and has used it to characterize a spectrometer that has potential to be used as an operational instrument.

The project received year-end funds from NRCAN (Varennes) that have been used to purchase necessary parts for the development of the operational spectrometer and helped in the purchase of a second potential instrument that will be tested in early 04-05

The summer observations of spectral irradiance are some of the first such observations in Canada. These observations show the significant effect of forest fire smoke on spectral irradiance, even after being transported in the atmosphere for more than 1000 km. Work continues on analyzing this data in collaboration with Simon Fraser University.

A recent IEA SHCP Task definition workshop has included the need for spectral resource assessment within its mandate. This task is expected to receive final approval in 2004 and will provide a means of developing global linkages in technologies associated with spectral irradiance.

Funding

The average resources allocated for this project per fiscal year were $59,000 (2002-2003 only). An average 32.2% of these resources came from PERD funds, the rest came from other sources (A-Base, others such as NRCan, Simon Fraser University). The average leverage quotient of total resources to PERD resources for the project was 3.1.

EC Wind and Solar Energy Resource Assessment- Wind Mapping with Atmospheric Models

Project Manager: Robert Benoit

Project Objectives

The project *Wind Mapping with Atmospheric Models* does not stem from another PERD project and is not part of a bigger project. Its objectives include:

- Improved wind forecasts to improve the economic efficiency, performance, and power generated from grid-connected wind energy systems supplying de-regulated electrical energy markets.
- Optimized siting and power production of renewable energy systems through improved wind energy resource assessment information.

This project benefits EC by improving the knowledge of the modeling of surface winds in Canada it also connects the MSC (Met Service of Canada) with another industry: windpower farms.

Methodology

The objectives of the project will be attained via:

- Large-scale climate data classification;
- Statistical-dynamical downscaling of wind data: development for mesoscale weather model;
- Coupling with micro-scale flow model;
- Use of high-resolution terrain data

Goals, Outputs and Project Success Story

The project has set the following goals:

- Participation and completion of IEA wind forecasting Annex by 05/06;
- Increase of accuracy of wind forecasts by 5% by 05/06;
- Verification of WEST (wind energy simulation toolkit, based on mesoscale MC2 model) modelling tools with tall towers (40m) in lower St. Lawrence Valley by 03/04;
- In partnership with NRC develop an ENSIM-based operational version of WEST for transfer to other agencies, companies and consultants by 03/04.

The project is advancing generally on target. Some highlights of this project include an article in TIMES magazine of Nov 18 2002: "The future is blowin' in the wind" and another article in Canada Research Horizons Spring 2003: "WEST wind blowing".

Funding

The average resources allocated for this project per fiscal year were $180,000 (2001-2002; 2002-2003). An average 38.9% of these resources came from PERD funds, the rest came from other sources (A-Base and industry). The average leverage quotient of total resources to PERD resources for the project was 2.6

Strategic Intent 5 · Strategic Direction 2

Strategic Direction 2 is to provide S&T to reduce emissions and the associated environmental impacts from centralized, combustion-based electric power generation systems.

Strategic Intent 5 · Strategic Direction 2 · Objective 5.2.1

The Characterization of Canadian Fuels and their Emissions (COFE) for More Efficient and Environmentally Benign Electricity Generation.

POL 5.2.1—Characterization of Canadian Fuels and their Emissions (COFE)
Canada's largest remaining hydrocarbon resource is contained in coal seams distributed in diverse geological settings from coast to coast (coal constitutes 90% of North America's remaining hydrocarbon resources). These coal seams also contain potential unconventional methane resources. New technologies for surface and in situ gasification indicate coal can be a major source of petrochemical products now refined from oil and gas. Deep coal seams also have potential as storage sites for greenhouse gases from Canada's electricity generation and conventional hydrocarbon sectors. Higher efficiency technologies for coal-fired electrical generation coupled with new emissions control technologies indicate coal can contribute to greenhouse gas reduction targets while maintaining environmental standards.

This POL focuses on the characterization of Canadian fuels and their emissions for more efficient and environmentally benign electricity generation.

Highlights within this POL include preliminary results from NRCan research on the characterization of emissions and by-products from coal-burning power plants. Data illustrate the true impacts of this activity, as opposed to the often emotional assertions expressed by the general public. For example, preliminary results indicate one-third of the particulate matter emitted is non-respirable. The particulate emissions from a modern coal-fired power using highly efficient particulate control technology can achieve, and even surpass, the National New Source Emission Guideline of 0.095Kg/Mwh for PM. An EC project has shown that certain components of coals are strongly correlated to increased mercury capture. These components are present in some coals but not in others. The implication of this is it may be possible for power plants to reduce mercury emissions by fuel switching or by blending the beneficial coal with the typically used coal. Methods which can be employed to reduce emissions of mercury will provide options to the electric power generating sector to meet air emissions criteria.

The following activities are included under POL 5.2.1:

- Fuel Characterization for Sustainable Production and Environmental Risk Assessment
- Resource Management Technology Development
- Emissions Characterization and Environmental Monitoring

Each project in POL 5.2.1 involves collaboration with academia (e.g. University of Kentucky), industrial partners (e.g. Trident Exploration Limited, DM Solutions Group Limited, Atco Electric Limited,, Fording Coal Limited, etc.), and provincial government agencies (Nova Scotia department of Natural Resources, Government of Yukon, British Columbia Geological Survey Branch, etc.) in collaboration with federal research groups for delivery. Federal Departments involved in this POL include NRCan and EC. The Geological Survey of Canada provides overall co-ordination.

For 2001-2002 and 2002-2003, the POL plan included 3 main projects. POL 5.2.1 is in its last year of a 3-year POL Plan. EC is leading 1 of these projects.

The total 2001-2002 annual budget for POL 5.2.1 was $1,875,000 and $1,851,000 for 2002-2003. The total PERD resources available for 2001-2002 were $741,000 and for 2002-2003, $711,000. PERD funds were divided amongst the departments involved in this POL (see Table 13). For this POL, the leverage quotient of total resources to PERD resources for 2001-2001 was 2.5 and 2.6 for 2002-2003.

Table 13. Percentage of PERD Funds for POL 5.2.1 Allocated to Each Department

Department	Percentage of Funds (%)	
	2001–2002	2002–2003
NRCan	86.9	86.8
EC	13.1	13.2

Profiles by Strategic Intent

Electricity Sector

Characterization of Canadian Fuels and their Emissions

Contaminants in Coal and Coal Byproducts

Environment Canada Projects for POL 5.2.1

Environmental Contaminants in Coal and Coal Byproducts

Project Manager:

Project Objectives

This project stems from projects carried out through the 1980s and 1990s. Most recently the work was carried out under the title *Advanced Combustion Emissions Controls* as part of PERD funded research. This work is a part of Activity 3 of POL 5.2.1, namely: The characterization of emissions from Canada's major centralized power generation plants in terms of trace and other elemental contaminants, as well a particulates and polyaromatic hydrocarbons. The main objective of this work is to determine the effect of these contaminants on emissions with a view towards the development of emission reduction strategies.

This work helps benefit EC since research in the area of coal combustion and coal byproducts helps develop a thorough understanding of the environmental impacts of fossil-fired electricity generation systems and thereby allows the Electricity and Industrial Combustion Branch to assess options for prevention, reduction or mitigation of these impacts. This knowledge aids in informing the Minister of the Environment on current issues of concern and in the development of appropriate policy to address these issues. Specifically, this research has enabled informed decisions on the following Environment Canada initiatives: the Multi-Pollutant Emissions Reductions Process for the Electric Power Sector, the revisions to the CEPA 1999 New Sources Emission Guidelines for Thermal Electricity Generation, and the Canada-wide Standards for Mercury from Coal-fired Electric Power Plants

Methodology

This work is comprised of laboratory and field investigations into the analyses of coal feed stocks, the ash-byproduct and the emissions to atmosphere from coal-fired boilers. The goal is to determining the quantification of the contaminants (e.g., heavy metals), the factors that affect the transformation and speciation of these contaminants, and to identify strategies for preventing or minimizing the release of these contaminants.

Goals, Outputs and Project Success Story

The main goal of this project is to try to determine what characteristics of coals and their constituents affect the ability for mercury in the coal to be captured in the fly as opposed to being emitted to atmosphere. This study will continue into 2004/2005.

Recent work has shown that certain components of coals are strongly correlated to increased mercury capture. These components are present in some coals but not in others. The implication of this is it may be possible for power plants to reduce mercury emissions by fuel switching or by blending the beneficial coal with the typically used coal. Methods which can be employed to reduce emissions of mercury will provide options to the electric power generating sector to meet air emissions criteria such as the impending CCME Canada-wide Standards for Mercury from Coal-Fired Power Plants.

Funding

The average resources allocated for this project per fiscal year were $120,000 (2002-2003 only). An average 50% of these resources came from PERD funds, the rest came from other sources (industry). The average leverage quotient of total resources to PERD resources for the project was 2.0.

Strategic Intent 5 ·Strategic Direction 2 ·Objective 5.2.2

The Conversion of Fossil Fuels to Electricity More Efficiently with Ultra-low Environmental Emissions.

POL 5.2.2—Clean and Efficient Combustion Technologies for Large Utility Electricity Generation

The generation of electricity by fossil fuel combustion is a major source of air contaminants worldwide. Approximately two-thirds of the world's electricity is generated by burning coal, natural gas and oil. In Canada, fossil fuels (70% coal, 18% natural gas, 7% oil and 5% biomass) account for 27% of the electricity generated. It is clear that this form of electricity production contributes to emissions affecting air quality, in the form of nitrogen oxide (NO$_x$), sulphur dioxide (SO$_x$), particulate matter (PM) and mercury (Hg).
This POL focuses on the assessment and development of technologies to convert fossil fuels to electricity more efficiently and with ultra-low emissions.

Highlights within this POL include products that have been developed, tested and are now in operation within industry; these projects have had significant cost recovery from clients. Here are a few examples. Testing for the capture and removal of Hg emissions from coal-based gases is underway for a major Canadian coal-fired utility. In an EC project, results have indicated that mercury control for lignite-fired power plants may be achievable. These encouraging results have led to the development of a larger demonstration project by SaskPower at one of its lignite-fired plants. As part of the same EC project, a new methodology will allow the measurement, tracking and reporting of the ultra-fine particulate emissions which are not presently represented in emission inventories. A more accurate quantification of these emissions will allow industry, atmospheric modelers and policy makers to devote the necessary resources to properly address the associated issues of air quality. A new measurement methodology for fine particulate matter from coal combustion has also been successfully demonstrated.

The following activities are included under POL 5.2.2:

- Upgrading of Existing Technologies (R&D on improved thermal efficiencies and reduced GHG emissions from existing generating stations).
- Air Quality Technologies (Determination of potentially hazardous substances in combustion residues)
- Advanced Electricity Cycles (Advanced, high-efficiency, clean combustion cycles for electricity)

Collaboration with CIDA and the Chinese Government has seen an implementation plan for technology transfer to reduce GHG emissions from coal fired plants in China. Canada is participating along with 10 other countries to IEA Bioenergy Agreement (Energy from Integrated Solid Waste Management Systems). Trough this POL, Canada also participates to the International Energy Agency (IEA) implementing Agreement on Clean Coal Sciences.

Funding sources and partnerships include NRCan, EC, universities (Southern Illinois University), industry (e.g. Kinectrics, TransAlta, ZECA Corporation, etc.) and other agencies (e.g. CIDA).

For 2001-2002, the POL plan included 19 projects and approximately 20 projects in 2002-2003. POL 5.2.2 is in its last year of a 3-year POL Plan. EC is leading 1 of these projects.

The total 2001-2002 annual budget for POL 5.2.2 was $3,269,000 and $4,093,000 for 2002-2003. The total PERD resources available for 2001-2002 were $1,997,000 and for 2002-2003, $1,935,000. PERD funds were divided amongst the departments involved in this POL (see Table 14). For this POL the leverage quotient of total resources to PERD resources for 2001-2002 was 1.6 and 2.1 for 2002-2003.

Table 14 Percentage of PERD Funds for POL 5.2.2 Allocated to Each Department

Department	Percentage of Funds (%)	
	2001–2002	2002–2003
NRCan	85.4	85.4
EC	14.6	14.6

Environment Canada Projects for POL 5.2.2

Profiles by Strategic Intent

Electricity Sector

Conversion of Fossil Fuels to Electricity

Pollution from Stationary Combustion Sources

Prevention, Control and Mitigation of Pollution from Stationary Combustion Sources

Project Manager: Don Rose

Project Objectives

This project stems from projects carried out through the 1980s and 1990s. Most recently the work was carried out under the title *Advanced Combustion Emissions Controls* as part of PERD funded research. This work is part of two Activities under POL 5.2.2. These are: *Air Quality Technologies – The determination of potentially hazardous substances in combustion residues;* and *Advanced Electricity Cycles – Advanced, high-efficiency, clean combustion cycles for electricity.*

The project benefits EC because research in the area of fossil-fired electricity generating systems helps develop a thorough understanding of the environmental impacts of these systems and thereby allows the Electricity and Industrial Combustion Branch to assess options for prevention, reduction or mitigation of these impacts. This knowledge aids in informing the Minister of the Environment on current issues of concern and in the development of appropriate policy to address these issues. Specifically, this research has enabled informed decisions on the following EC initiatives: the Strategic Options Process to address emissions of toxic substances, the Multi-Pollutant Emissions Reductions Process for the Electric Power Sector, the revisions to the CEPA 1999 New Sources Emission Guidelines for Thermal Electricity Generation, and the Canada-wide Standards for Mercury from Coal-fired Electric Power Plants.

Methodology

The current work is comprised of several areas of studies carried out with federal, provincial and academic research institutions. The work involves laboratory and field investigations into:

- Laboratory investigation of sorbents for mercury capture from power plant stack gases;
- Laboratory and field investigation of coal gasification technology and its implications/impacts for the Canadian electricity industry and indigenous coal reserves;
- Laboratory and field development of a methodology for measurement of the condensable fraction of fine particulate matter; and
- aboratory development of an advanced technique for the real-time sampling, measurement and monitoring of ambient aerosol particulate matter.

Goals, Outputs and Project Success Story

Sorbents for mercury capture from power plant stack gases:

- A recently completed study was carried out at the Energy & Environmental Research Center (EERC), University of North Dakota. This pilot-scale study examined potential mercury control options for electric power plants that burn lignite coal. The findings were that mercury capture at lignite-fired power plants may be achievable. These results are being used to design a larger scale project at a Saskatchewan lignite-fired power plant.

- A current study is being carried out by the Saskatchewan Research Council (SRC) and affiliates. The purpose of this is an attempt to determine the properties and mechanisms of sorbents for potential capture of mercury from coal-fired power plants. The results of this would benefit the field test work described above. Work is to be completed by March 31, 2004, and a report will be made available at that time.

Coal gasification technology and its implications/impacts for the Canadian electricity industry and indigenous coal reserves:

- This is an on-going study into the state of the art of coal gasification. The principal investigator is CANMET Advanced Combustion Technology Centre. This project is expected to continue well into the future, as it appears that coal gasification has been deemed by the fossil-fired electricity generating utilities to be the technology of choice for the next generation of power plant. This continued technology watch will help evaluate the environmental performance of such plants. Yearly reports are prepared and are available. This watching brief on gasification technology will continue into 2004/2005.

Methodology for measurement of the condensable fraction of fine particulate matter:

- This work is being carried out by CANMET Advanced Combustion Technology Centre in collaboration with two Canadian electric utilities. The purpose of the work is to devise a method for the measurement of the ultra-fine, condensable fraction of PM in coal-fired combustion systems. Previous laboratory work proved the concept and equipment is feasible and field trials in 2003/2004 further confirmed the techniques. Regular progress reports and annual reports are prepared by CANMET (The reports are not available as they are Business Protected under agreements with the utilities). A review at the end of this fiscal year will determine the future of this project.

Advanced technique for the real-time sampling, measurement and monitoring of ambient aerosol particulate matter:

- This work is carried out by the University of Toronto (UofT) Department of Chemistry and Chemical Engineering. Previous work investigated and proved the concept of using the novel technique of laser ablation mass spectrometry (LAMS) to physically and chemically characterize ambient particulate matter in real time. Further work involved the construction of a LAMS unit at UofT for sampling ambient PM and the development of techniques for sorting and analyzing the data. Laboratory work is expected to continue through to 2004/2005. It is intended that the LAMS technology would be brought from the laboratory to the field for final development with the ultimate goal of the broader application of identifying extreme PM events as they occur and of identifying the source of the PM emissions. Yearly reports are available. This project will continue into 2004/2005.

Some success stories within this project include:

Sorbents for mercury capture from power plant stack gases:
The EERC study indicated that mercury control for lignite-fired power plants may be achievable. These encouraging results have led to the development of a larger demonstration project by SaskPower at one of its lignite-fired plants.

Coal gasification technology and its implications/impacts for the Canadian electricity industry and indigenous coal reserves:
The past years of investigation of this topic have helped create a unique Canadian expertise at CANMET. Following on this level of expertise and the industry's acceptance of the technology for a future plant, CANMET is constructing its own pilot-scale gasification research facility. This will allow more in-depth research on the workings of a gasification unit and on the applicability to Canadian fuels.

Methodology for measurement of the condensable fraction of fine particulate matter:
The benefit of this methodology will be to allow the measurement, tracking and reporting of the ultra-fine particulate emissions which are not presently represented in emission inventories. A more accurate quantification of these emissions will allow industry, atmospheric modelers and policy makers to devote the necessary resources to properly address the associated issues of air quality.

Advanced technique for the real-time sampling, measurement and monitoring of ambient aerosol particulate matter:
Present methods for measuring and reporting ambient particulate loadings involve the use of stationary sampling stations. These require a period of days to weeks to gather the samples and then have them analyzed in laboratories. As such, any effort taken to address major PM events would be after the fact. The unqualified success of the real-time LAMS techniques is that they provide the instantaneous classification, quantification of and identification of the source of the ambient PM. This could allow immediate action to be taken, so as to negate or minimize the negative effects of the event.

Funding
The average resources allocated for this project per fiscal year were $678,000 (2002-2003 only). An average 47.6% of these resources came from PERD funds, the rest came from other sources (Industry and others). The average leverage quotient of total resources to PERD resources for the project was 2.1.

Profiles by Strategic Intent

Electricity Sector

Capture, Treatment, Transport, Use and Storage of CO_2

Strategic Intent 5 ·Strategic Direction 2 ·Objective 5.2.3

The Capture, Treatment, Transport, Use, and Storage of CO_2 from Large Point Sources.

POL 5.2.3—CO2 Capture and Storage

Industrial GHGs combined with natural sources are overwhelming the ability of natural sinks to maintain the atmospheric balance at earlier levels. Anthropomorphic input must be limited. Of the available electricity production methods, burning fossil fuels is very common (27% of generated electricity) and produces the highest levels of GHG emissions. The development of artificial carbon sinks is a solution to cleaner production of electricity via fossil fuel combustion. POL 5.2.3 links separate but related science and technology initiatives presently underway to develop the "zero emission power" option of Canadians. The impact of this program will be felt in years to come when technology and incentives combine to create opportunities for industry to capture and sequester CO_2 from large central power plants.

One highlight of this POL involves the use of CO_2 as an adsorbing material in the extraction of coal bed methane (CBM) to enhance the extraction of methane gas in the coal seams. An EC project under this POL uses this principle and offers a sophisticated solution to the problem of CO_2 emissions. CO_2 produced from a generating station could be pumped into the coal bed to enhance CBM recovery at an extraction site. A study to identify the CO_2 adsorptive capacity of two representative coals extracted from coalbed methane exploration well in Alberta was successfully completed. Results confirm the potential for CO_2 storage.

The following activities are included under POL 5.2.3:

- O_2/CO_2 Process Simulation
- O_2/CO_2 Laboratory Pilot Plant
- CO_2 Condensor Process Simulation
- CO_2 Condensor Laboratory Pilot Plant
- Coal Bed Methane Field Pilot
- Ocean Disposal Field Pilot
- Analysis of CO_2 Adsorption Capacity of Coal

This POL has participated in numerous international initiatives in promoting Canada's climate change technology developments, such as the participation in the development of the IEA Zero Emissions Technologies task force, participation with US DOE and industry in the oxy-fuel research program, providing input to the international data base of projects and participants established by the IEA Greenhouse Program on CO_2 and many more activities.

Funding sources and partnerships include federal departments and programs such as NRCan, EC, Fisheries and Oceans Canada, the CCAP (Climate Change Action Plan), universities (Carleton University, University of Waterloo), industry (e.g.McDermott Technologies Inc., Air Liquide Canada, etc.), provincial generating companies (Saskatchewan Power, Ontario Power Generation, Nova Scotia Power, etc.) and other agencies.

For 2001-2002 and 2002-2003, the POL plan included 13 projects. EC is leading 1 of these projects in 2002-2003.

The total 2001-2002 annual budget for POL 5.2.3 was $1,422,000 and $5,025,000 for 2002-2003. The total PERD resources available for 2001-2002 were $1,070,000 and for 2002-2003, $1,049,500. PERD funds were divided amongst the departments involved in this POL (see Table 15). For this POL, the leverage quotient of total resources to PERD resources for 2001-2002 was 1.3 and 4.8 for 2002-2003.

Table 15 Percentage of PERD Funds for POL 5.2.3 Allocated to Each Department

Department	Percentage of Funds (%)	
	2001–2002	2002–2003
NRCan	70.8	67.7
EC	20.1	19.1
DFO	9.1	13.3

Environment Canada Projects for POL 5.2.3

Coal Bed Methane Field Pilot- Characterization of Injected CO_2 and Impact on CBM

Project Manager: Bill Reynen

Project Objectives

This work stems from PERD #22104 in which Phases 1 and 2 were completed (1998). During 1998, as single well micro-pilot test of Mannville coal seams in the Fenn Big Valley area of Alberta was completed. During Phase 2, pure CO_2 injection was tested and concluded that excellent sweep characteristics for the CBM reservoir could be obtained. The principal investigators for the proposed study are staff of the Alberta Research Council (ARC), with Dr. William Gunter heading the technical team. Members of the program include industry, international governments, researchers, provincial and federal governments.

The main objective of this project is to reduce greenhouse gas emissions by subsurface injection of carbon dioxide into deep coalbeds and to assess the technical feasibility of CO_2 disposal while enhancing coal bed methane (CBM) production. It involves the use of CO_2 as an adsorbing material in the extraction of CBM to enhance the extraction of methane gas in the coal seams. This project is part of POL 5.2.3 and corresponds to Activity 5, namely *Characterization of injected CO_2 and impact on CBM.*

This project benefits EC since it directly relates to EC's cleaner air mandate by reducing industrial GHGs. The development of artificial carbon sinks such as the use of CBM production is a solution to cleaner production of electricity via fossil fuel combustion. This project will directly affect technology and will create an opportunity for industry to capture and sequester CO_2 from large central power plants.

Methodology

- Phase I was an initial assessment and feasibility study of the concept of injecting industrial waste gas streams containing CO_2 into Alberta's Mannville coals. This phase was completed in July 1997 and it was concluded that flue gas injection was feasible and that the project should continue.
- Phase II consisted of the design and implementation of a micro-pilot test at Fenn-Big Valley, Alberta where injection of pure CO_2 into coalbeds was tested. Phase II was successfully completed in April, 1999 and it was determined that a full scale CO_2 sequestration/enhanced gas recovery (EGR) pilot project was possible.
- Phase III, the design and implementation of a full-scale pilot project in the Fenn-Big Valley area has been divided into two parts. Part A was completed in October, 2000, and focused on the design of a surface facility at commercial and pilot scales, the testing of synthetic flue gas compositions (CO_2/N_2 mixture) in micro pilot tests and testing pilot scale flue gas generation and injection facilities. Part B consists of the operation of a full scale pilot, based on the results from Part A. The full scale pilot will demonstrate that commercial scale CO_2 sequestration in coalbeds with enhanced methane recovery is possible.
- Phase IV is currently underway and involves matching sinks and sources to foster more pilot demonstrations.

Profiles by Strategic Intent

Electricity Sector

Capture, Treatment, Transport, Use and Storage of CO_2

Coal Bed Methane Injected CO_2

Outputs, Goals and Project Success Story

- Two representative coals were collected from coalbed methane exploration wells in east central Alberta through the EnCana/MGV coalbed methane joint venture.

- These samples had already been ground and subjected to methane isotherm by Terratek laboratories of Salt Lake City, Utah. The samples were then submitted for CO_2 isotherm analysis as part of the work plan for this project.

- All laboratory analyses were completed successfully. CO_2 adsorptive capacity was determined at resevoir pressures from 0 to 6 Mpa and at temperatures of 15°C, 20°C and 25°C. Methane adsorptive capacity were determined at the reservoir temperature of 16°C.

Several papers have been presented in international fora. Much of the work is still confidential.

The pilot projects have successfully demonstrated the technical feasibility of CO_2 disposal while enhancing CBM production. Canada is now recognized as a leader in enhanced coalbed methane (ECBM) research. The technology associated with ECBM is on the public policy agenda as a potential mechanism for significant reductions of GHGs.

The project has now completed four micro-pilot tests in western Canada to assess reservoir response in Mannville coals. The data obtained from these tests was used to calibrate reservoir simulators in order to estimate the CO_2 storage/enhanced hydrocarbon gas recovery potential of a multi-well pilot being planned. An important milestone was reached with the selection of a site for the multi-well pilot. The research consortia is now considering other sites for development. The consortia is negotiating with a modeling software vendor to incorporate design aspects developed within the consortia into a commercial model.

Funding

The average resources allocated for this project per fiscal year were $2,285,000 (2001-2002; 2002-2003). An average 8.3% of these resources came from PERD funds, the rest came from other sources (Industry and others). The average leverage quotient of total resources to PERD resources for the project was 12.0.

Profiles by Strategic Intent

Climate Sector

Impacts of Climate Change on the Energy Sector

Profiles by Strategic Intent

Climate Sector

Impacts of Climate Change on the Energy Sector

Strategic Intent 6—Climate Sector

Strategic Intent 6 is to minimize the negative impacts of climate change on the Canadian energy sector.

Strategic Intent 6 · Strategic Direction 1

Strategic Direction 1 is to provide S&T to support the Canadian energy sector's response to the impacts of climate change.

Strategic Intent 6 · Strategic Direction 1 · Objective 6.1.1

The Development of a Better Understanding of the Impacts of Climate Change on the Energy Sector, Improvement in the Forecasting of Those Impacts, and the Development of Some Possible Response Strategies.

POL 6.1.1—Climate Change Impacts on the Energy Sector (CCIES)

Greenhouse gas concentrations are on the increase and will continue to be so even with a full implementation of the Kyoto Protocol to the United Nations Framework Convention on Climate Change. The result is climate change. The energy sector (production, transmission, distribution and demand) will be affected by changes in temperatures (changes in seasonal heating and cooling demands), sea level rise, sea ice regimes, land stability, hydrological cycles, wind regimes and cloud cover as well as changes in extreme events. Climate change research, conducted in Canada, will enhance our understanding of the climate system and improve our ability to forecast future climate. These forecasts will be most robust when presented at global scales; this POL addresses the challenge of both downscaling these predictions and presenting them in the appropriate parameters so that they can be used to assess the impacts on the energy sector in various regions of Canada.

Anticipating the impact on the energy sector and formulating response strategies begins with a basic understanding of climatic events. Two of the many excellent projects led by EC in this POL can highlight these efforts. A project in North Western Canada is looking at historical temperature and hydrological data to determine if their pattern of natural variation suggests a climate change signal already exists. Climate modeling techniques will be evaluated and further developed to assess the effects of past and future climate change on the regional hydrologic system. A change in glacial resources or the thickness of the permafrost layer may have significant effects on hydroelectric generation or on transportation of oil and gas via pipeline from this region. In the Gulf of St. Lawrence region a similar study is attempting to develop a coupled air-ice-ocean localized climate model capable of predicting the high frequency and seasonal changes in the weather, currents, ice, and the heat/salt/nutrient/momentum content and fluxes in the Gulf. Like its western counterpart, a successful outcome will provide evidence of climate change and predict effects on the hydrological cycle. Such knowledge could be used to assess the possible impact of changes on onshore hydroelectric generation, on offshore oil and gas platforms, and on the safety of marine transportation to and from these sites.

The following activities are included under POL 6.1.1:

- The potential impacts of climate change on energy production.
- The potential impacts of climate change on energy transmission and distribution.
- The potential impacts of climate change on energy demand.

This POL is funded by the following federal departments: NRCan, EC and Fisheries and oceans. Other funding sources include universities, industry (Ouranos, Manitoba Hydro, various east coast Oil and Gas operators), as well as other sources (CCAF, CCRS, CSA, US office of Global Programs, Australia CSIRO, PCSP, NREI) and other POLs.

For 2001-2002, the POL plan included 21 projects and 22 projects in 2002-2003. POL 6.1.1 is in its second year of a 3-year POL Plan. EC was leading 11 of these projects in 2002-2003, one of these projects is in collaboration with DFO.

The total 2001-2002 annual budget for POL 6.1.1 was $6,843,700 and $6,603,400 for 2002-2003. The total PERD resources available for 2001-2002 were $2,148,000 and for 2002-2003, $2,109,000 (latest figures obtained in March 2004, however, for the breakdown within the departments, PAR figures were used ie $2,108,000 for 2001-2002 and 2002-2003). PERD funds were divided amongst the departments involved in this POL (see Table 16). For this POL, the leverage quotient of total resources to PERD resources for 2001-2002 was 3.2 and 3.2 for 2002-2003.

Table 16 Percentage of PERD Funds for POL 6.1.1 Allocated to Each Department

Department	Percentage of Funds (%)	
	2001–2002	2002–2003
DFO	50.2	51.2
EC	40.3	38.3
NRCan	9.4	10.4

Environment Canada Projects for POL 6.1.1

Historical and Future Climate for the Assessment of Energy Sector Impacts in Canada

Project Manager: Don MacIver

Project Objectives

The main objectives of this research are to:

- To develop a nationally consistent set of energy sector historical and future climate scenarios that address impacts researchers' and decision-makers' defined needs and are consistent with other sectoral impacts information being developed within the Canadian Climate Impacts Scenarios (CCIS) Project.
- To make energy sector scenario available and provide guidance to the research community and other users.
- To engage representatives of the energy sector in updating the energy sector chapter of the Canada Country Study based on the available historical and future climate scenarios.

EC benefits from this project through enhancing in-house capacity to develop climate scenarios for the energy sector, improved climate data analysis, tool development and being able to engage the energy sector.

Methodology

- Web workshop to determine the scenario information required by stakeholders;
- Development of statistical analysis tool which was used for data analysis;
- Statistical downscaling of climate scenarios using SDSM and LARS-WG software.

Goals, Outputs and Project Success Story

- A Synthesis Report of the Web-Workshop on Climate Scenarios;
- Climate analysis products of 460 stations across Canada;
- Statistical Tool for Extreme Climate Analysis (STECA);
- A report entitled " Climate Change and the Canadian Energy Sector: Report on Vulnerability, Impact and Adaptation";
- Statistical downscaled scenarios for 57 stations across Canada for the CGCM1 model.

Future goals for 2004/2005 include:

- Statistical downscaling of scenarios for the HadCM3 model;
- Analysis of climate extremes;
- Posting on the CICS website.

Highlights resulting from this research include:

- Climate analysis products of 460 stations across Canada;
- Statistical Tool for Extreme Climate Analysis (STECA);
- A report entitled " Climate Change and the Canadian Energy Sector: Report on Vulnerability, Impact and Adaptation";
- Statistical downscaled scenarios for 57 stations across Canada for the CGCM1 model.

Funding

The average resources allocated for this project per fiscal year were $101,500 (2001-2002; 2002-2003). An average 90.2% of these resources came from PERD funds, the rest came from other sources (A-Base). The average leverage quotient of total resources to PERD resources for the project was 1.1.

Impacts of Climate Changes in the Canadian Inland Seas Watershed on the Canadian Energy Sector

Project Managers: Gérald Vigeant and Jean-Claude Therriault (DFO)

Project Objectives

This project stems from a previous PERD project. The research was first initiated in 1998-1999 with the development of the first coupled ice/ocean/atmosphere models in view of assessing the impact of climatic changes in the Gulf of St Lawrence. PERD funding has helped in the development of a solid expertise in this field. This project is not part of a bigger project. However, participating researchers and scientific results are part of other scientific programs such as NSERC/CLIVAR, CFCAS, CCAF, Ouranos Consortium, ARCTIC NET/CLIC, etc.

The objectives of this project are in direct support of the CCIES Program at Objective Level aiming at the production of climate scenarios and enhanced environmental predictions adapted to the production, transmission, and demand in the energy sector. As of now, it is yet impossible to downscale climate scenarios to the Canadian inland seas watershed for the lack of an appropriate representation of the coupling between the atmospheric, oceanic, hydrologic and continental components. This project aims at filling this gap in order for the energy sector, as well as many other sectors of development, to fully benefit from the capability to precisely downscale and make use of climate change scenarios and extreme event predictions. It ensures, for the first time, the closure among the expert teams that can carry both the modeling and analysis work toward the energy sector in the Canadian inland seas watershed.

- Develop a regional climate model for Northeastern North America that incorporates coupled atmospheric, continental, basin-scale hydrological, and estuarine ice-ocean components;
- Develop the predictive capability for extreme meteorological and oceanic events in the Canadian inland seas watershed;
- Produce climate change scenarios and impact analyses for the Canadian Energy Sector;
- Foster adaptive responses and decision making regarding environmental predictions in the Canadian Energy Sector.

This project has been able to maintain and encourage EC's efforts in coupled ice/ocean/atmosphere modelling which is of utmost importance for Canadian Northeastern Inland Seas (Hudson Bay/Ungava Bay, Gulf of St Lawrence and estuary. The project has developed research in this field (M.Sc/Ph.D theses) and has gained acknowledgement in the development of climatic scenarios. It's scientific programs and research have been accepted by partners such as Civil Security, the Coast Guard, OURANOS consortium, etc. and have helped in the harmonization of climatic adaptation scientific programs.

Methodology

Through the Canadian climate modelling network of experts, a coupled regional climate model has been developed to reproduce the known climate over the Canadian inland seas watershed, including the atmospheric (north-eastern America), hydrologic (basin-scale inland seas surface runoff), estuarine (Gulf of St. Lawrence, Hudson Bay/Foxe Bassin), and continental components (Canadian Land-Atmosphere Surface Scheme). For these highly-sensitive areas and watersheds, different coupled ice/ocean/atmosphere models have been developed and validated in order to be able to reproduce the past and current variability (seasonal and synoptic scales), and quantitatively estimate changes induced by increased greenhouse gases on extreme events (e.g., storm surges, drought, heat waves, heavy precipitation), or by fresh water regime, currents and the ice cover climate related modifications.

Feedback associated with air-sea fluxes, clouds, shelf fronts, mesoscale oceanic features and sea-ice will be investigated for improving the needed downscaling of large-scale ocean climate models and to enhance coastal climate change projections. Resolving the problem of integrating continental surface fluxes into the Canadian Regional Climate Model becomes critical to the development of sound and realistic regional climate scenarios over continental areas in northeastern Canada. This scientific barrier has to be overcome if the Canadian energy sector needs to assess the impacts of climate change on future hydrological flows and to determine the frequency/intensity of extreme events such as heavy rainfalls and droughts. A strong push is now needed among the Canadian regional modelling community to find a solution to that scientific obstacle.

By making government and industry decision-makers aware of expected hydrological, land surface, biological and oceanographic changes due to climate change, we will elaborate and conduct vulnerability studies, on a regional scale, related to hydroelectric production, marine transportation in ice-infested sectors, vulnerability of municipalities and native communities to climate change as well as an assessment of the sustainability of existing and planned infrastructures located in the Gulf and Estuary of St. Lawrence, Hudson Bay and Ungava Bay watersheds as well in north-eastern Canadian continental basins.

The following team of experts and specialists is identified for this project : Atmospheric and continental components : René Laprise and Daniel Caya (UQAM), Jennifer Milton, Jeanna Goldstein, Manon Faucher, Khanh-Hung Lam (Environment Canada), Vincent Fortin (Institut de recherches électriques du Québec); Estuarine and oceanic components : Francois J. Saucier, Denis Gilbert & François Roy (DFO), Jia Wang (University of Alaska). The project will also involve the participation of PDF Philippe Gachon (DFO), Ph.D. Manon Faucher (UQAM) in addition to 3-4 graduate students throughout the duration of the proposed project as well as the participation of scientific partners (e.g. OURANOS) in the project.

Goals, Outputs and Project Success Story

The present project aims at developing regional ice-ocean models of the Gulf of St. Lawrence and Hudson Bay that are suited for downscaling climate change scenarios. Since we need to bring the model equilibrium into a future state wherein no observations are available, restoring conditions to observations is not an option. Thus, a fully prognostic model was developed to reproduce the observed conditions over the past five years, a period

Profiles by Strategic Intent

Climate Sector

Impacts of Climate Change on the Energy Sector

Climate Changes in the Canadian Inland Seas Watershed

over which sufficiently accurate atmospheric forcing was available. The first results are reported in the publications and conferences cited below. Briefly, we have successfully accomplished major steps in overcoming the problems in modelling the synoptic to inter-annual changes in coupled ocean-sea ice conditions: (1) turbulence modelling now includes an energy equation that more accurately reproduces the mixed layer properties and depth over seasons (Smith et al., 2002; Saucier et al., 2002); (2) an elastic-viscous-plastic rheology has been implemented for sea ice dynamics; (3) we have reduced all hydrological and atmospheric forcing data and model results (including IPCC IS92a and b scenarios) for producing simulations over the past and future decades; (4) we have implemented the coupler developed by P. Pellerin at RPN (CMC, MSC) into the Canadian Regional Climate Model (CRCM). The new 10 km Hudson Bay system model has been designed for a straightforward implementation into this coupler. The coupler has already been used for incorporating the Gulf of St. Lawrence model into the Global Environmental Multiscale Model (GEM) Canadian weather forecast model. Preliminary results suggest that sea ice dynamics in the Gulf may change the weather by several degrees C during stormy winter events in eastern Canada (Pellerin et al., 2002;2003).

In the context of climate change, means are necessary to evaluate the range of possible impacts with respect to variations in greenhouse gas and sulphur emissions as well as demographic and economic developments. Climate change scenarios are based on the evaluation and inclusion of these parameters with results from GCM's (Global Climate Models) outputs and represent possible alternatives or story-lines on how the climate may change within the next century. Using the Intergovernmental Panel on Climate Change « Guidelines on the Use of Scenario Data for Climate Impact and Adaptation Assessment », climate scenarios based on GCMs outputs and LARS-WG Stochastic Weather Generator were developed for areas within the province of Quebec. Analysis of the climate projections (IPCC Data Distribution Centre) was performed using the results of the different climate change intergrations forced with IS92a and SRES (A1, A2, B1 and B2) emission scenarios.

Results for the Saint-Lawrence River area indicate that this region could experience increases in temperature in the order of 3 to 8 °C as a function of period of the year and level of emission forcing. Expected changes in climate and particularly in temperature distributions may thus produce significant impacts on the environment, ecosystems and society. The inclusion of climate scenarios in impact studies should thus be of prime interest for the evaluation of the range and extent of possible changes for such sectors such as agriculture, state of the Saint-Lawrence and other ecosystems as well as human infrastructures.

In order to evaluate the state of hydrological conditions in North-Eastern Quebec and Labrador and to link annual river runoff variability with respect to large-scale systems (Icelandic Low, North Atlantic Oscillation), an analysis of Quebec's northern latitude runoff conditions was performed for the period of 1950-2000. Results reveal that river runoff variability before 1970 is dominated by interannual fluctuations, whereas interdecadal fluctuations seem to underlie the pattern thereafter. Furthermore, evidence suggests that precipitation conditions during winter, and thus river runoff during spring, can be linked to the intensity, structure and spatial localisation of these large-scale systems (Lam, 2002).

Profiles by Strategic Intent

Climate Sector

Impacts of Climate Change on the Energy Sector

Climate Changes in the Canadian Inland Seas Watershed

Scientific advancements achieved through this PERD project have led to a great interest from several stakeholders such as:
The consortium Ouranos and one of his formal partner (Hydro-Québec) with respect to modelled precipitation in the northern Quebec watershed as well as the development of regional climate change scenarios:

- As demonstrated during the fall of 2001/2002, the late ice cover formation was related to large precipitation events filling the Hydro-Quebec reservoirs. It became clear to Hydro-Quebec that we need a much better understanding of the way the sea ice cover will evolve over the next decades in Hudson Bay, and how this may affect meteorological systems. The sea ice cover controls the formation and trajectories of polar lows over and in the eastern part of Hudson Bay. The sea ice cover reduction there may make more moisture available for precipitation over northern Quebec. The work by Gachon et al. (2002), Gachon and Saucier (2001), have shown that the details of the ice-cover conditions in the fall and early winter control the weather systems moving over the Hydro-Quebec northern reservoirs, and that the coupling between the ocean and the atmosphere is a necessary step toward building scenarios to estimate water availability in northern Quebec over the next century. Through this PERD project, we have recently successfully reproduced the seasonal ice-ocean cycle in Hudson Bay/Foxe Basin and Hudson Strait (Saucier et al., in Climate Dynamics). This new ice-ocean model was made operational in the framework of the CRCM and CLIVAR/CFCAS programs that are ongoing at Ouranos. Dr. Minwei Qian has coupled the ice-ocean model to through fluxes with the atmosphere, and is currently perfoming 5-year simulations of the regional climate (Qian et al., 2003). Note that the Government of Quebec is heavily relying on hydro-electricity for future development and negotiations on emission trading through the Kyoto Protocol. Because of the poor data coverage over years in Hudson Bay, the 2003 mission involving the Canadian Coast Guard ship of opportunity which deployed year-long moorings in the Hudson Bay system will become extremely benefitial to validate the ice-ocean model. Furthermore, since the hydro-electric resources of North-Eastern Quebec and Labrador are greatly dependent upon the precipitation and temperature patterns of the area, Lam (2002), in cooperation with scientists at Hydro-Quebec has studied the role of climatic and large-scale driving forces such as the Arctic High, the Icelandic Low and the polar vortex cycles (represented by the Arctic Oscillation (AO), on the annual river runoff variability patterns from 1951 to 2000. Oil exploration in the Gulf of St. Lawrence is another area of development that is very sensitive to the ice-ocean climate and is in need of long term information about the ocean climate. A meeting with Hydro-Quebec took place to examine the needs of environmental predictions for their planned exploration phase starting in 2003, and initial discussions took place on climate change impacts on eventual operations in the Gulf of St. Lawrence.

The Canadian Coast Guard with respect to a better understanding of the response of the sea-ice cover to climate change:

- Major efforts by port authorities and both the provincial and federal governments in Quebec, for expanding marine transportation in the St. Lawrence, may benefit from regional climate change scenarios for sea ice cover reduction, and better predictions for extreme events. Major shipping companies establish long term strategies, and those are based on cost/benefit analyses that should make use of climate change scenarios. Note that, yearly, commercial shipping on the St. Lawrence represents an industry 1.9 MM, indirectly leveraging another 3.1 MM, and carrying goods of 17 MM in value (SODES). The development of our capability to model the regional ice-ocean climate also directly provides information on the marine forecasting of sea ice, currents, freezing sprays, and waves, which supports more efficient and safe marine transportation. Oil exploration in the Gulf of St. Lawrence is another area of development that is very sensitive to the ice-ocean climate and has needs for long-term information.

The consortium Ouranos involved several impacts and adaptation researchers devoted to water resources, coastal erosion and permafrost in the North (Quebec Civil Protection Agency) and conflicting economic, environmental and social uses in the South:

Coupled ice-ocean regional climate models for the Estuary and Gulf of St. Lawrence, and Hudson Bay and Foxe Bassin have been developed with the aim of increasing our predicting capacity taking to account the possibility of downscaling climate change scenarios. The main results are reported in Saucier et al. (2003), Saucier et al. (2002), Senneville and Saucier (2002), and Smith et al. (2002). The coupling phase between ice-ocean models and the Canadian Regional Climate Model was achieved by Faucher (2002), Faucher et al. (2002, 2003), Gachon et al. (2002), Gachon (2001), Charpentier (2002), and Qian et al. (2003). The offline coupling of the Gulf of St. Lawrence model (Saucier et al., 2002c) was achieved over a complete seasonal cycle by Charpentier (2002). The Gulf of St. Lawrence ice-ocean model is fully coupled into the Global Environmental Multi-scale forecast model (operational Canadian weather forecast model). Pellerin et al. (in Monthly Weather Review) have demonstrated that the use of the fully interactive atmosphere-ice-ocean model improves the forecast skill for temperature, cloud cover, winds and sea ice dynamics on the Canadian east Coast. Significant efforts have been devoted to develop a rigourous methodology in the development and the use of climate change scenarios for the province of Quebec. Climate change scenarios are based on the evaluation and inclusion of these parameters with results from GCM's (Global Climate Models) outputs and represent possible alternatives or story-lines on how the climate may change within the next century. Using the Intergovernmental Panel on Climate Change « Guidelines on the Use of Scenario Data for Climate Impact and Adaptation Assessment », climate scenarios based on GCMs outputs and LARS-WG Stochastic Weather Generator were developed for areas within the province of Quebec (Goldstein, 2002). Analysis of the climate projections (IPCC Data Distribution Centre) was performed using the results of the

- different climate change integrations forced with IS92a and SRES (A1, A2, B1 and B2) emission scenarios. Results of that work regularly updated into the CRIACC web site (www.criacc.qc.ca) were used in other sectors (agriculture) and therefore could benefit to complementary research studies (Bourgeois et al, 2001). With respect to coastal erosion, the recent warm winters occurring in the Estuary and Gulf of St Lawrence resulted into less severe sea ice regime. Coastal regions were strongly flooded and eroded by surface waves and storm surges that were not as usually dampened by the land fast and first year ice that is usually present to protect the shore. For instance, the main highway along the southern coast of the Estuary runs along the shore and was frequently flooded during storms and high tides. On the North shore near large river estuaries, the sediment has been largely redistributed due to changes in the winter wave climate. This is important to infrastructure but also to attribute the correct cause of these changes as these rivers have had their peak flows being reduced though recent hydro-electric development. Several meetings have taken place with the provincial stakeholders to define the different regional problems, examine the past record, and plan the use of our the regional sea ice climate scenarios in controlling the set-up and propagation of surface waves and surges into the sensitive areas, in collaboration with K. Thompson at Dalhousie University. The daily forecast and climate change scenarios enter into the new operational high-resolution wind-wave models developed by Jacob et al. (2002) for the Gulf of St. Lawrence. The sea ice effects on wave generation and dissipation are accounted for, which provide a new powerful tool to downscale the wave climate to coastal regions with reduced sea ice cover due to global warming.

Funding

The average resources allocated for this project per fiscal year were $168,000 (2001-2002; 2002-2003). An average 59.9% of these resources came from PERD funds, the rest came from other sources (A-Base, others). The average leverage quotient of total resources to PERD resources for the project was 1.7.

Climate Change and Offshore Design Criteria

Project Manager: Val Swail

Project Objectives

This project is linked to the PERD OEF Wind and Wave Design Criteria project which produces many of the hindcast data bases used in this analysis. The project is also linked to a joint project with the Netherlands Meteorological Institute (KNMI) on a global wave reanalysis, and to work being carried out by the International Association of Oil and Gas Producers (OGP). The project is also coordinated with a second joint project with the US Army Corps of Engineers on wave climate indicators.

The International Association of Oil and Gas Producers (OGP) lists as one of its key issues "climate variability and its impact on offshore structure design", in particular to investigate storm trend and variability and to quantify whether apparent changes in mean and maximum values of wave height or number of storms were real trends or parts of a cyclical variation in the establishment of metocean design criteria, with particular emphasis on capital and operating cost reductions while maintaining responsible levels of safety. (reference:http://www.ogp.org.uk/committees/metoc/index.html). The objective of the joint project with the Netherlands Meteorological Institute is to help us describe wind, wave and storm variability on a global basis.

This project benefits EC since the determination of long term trend and variability in wind, wave and storm climatology is an important objective of the Climate Research Branch.

Methodology

The primary goal of this research project is to reduce the uncertainty concerning the potential impacts of climate change, in particular the frequency and/or intensity of extreme storms, on the wind and wave design criteria off the east coast of Canada. In order to achieve this goal the R&D plan has three important components:

- To homogenize wind and wave data sets from various observational and hindcast sources into a consistent, long term time series of wind, wave and storm data;
- To analyze those homogeneous time series for trends and variability and;
- To translate those research results into potential impacts on design criteria.

Goals, Outputs and Project Success Story

Work has been progressing ahead of schedule on this project, relative to the original project proposal. A significant change in the project scope has been the additional levering of Departmental A-Base resources to carry out related work on climate change scenarios through the 21st century, specifically dealing with expected changes in wind speed and wave height, and more recently the initiation of investigation into innovative new techniques for determining changes in extreme value analysis.

Outputs and Goals for 2001 to 2005 include:

Profiles by Strategic Intent

Climate Sector

Impacts of Climate Change on the Energy Sector

Climate Change and Offshore Design Criteria

- 2001/02- Report and presentation to oil industry and regulators on climate trend and variability – deliverable exceeded: (see list of publications and presentations) which has been expanded to include marine climate change scenario publications;

- 2002/03- Assessment of homogeneity of trends in extreme storms from hindcast and measurement. A series of papers relating to impacts of marine climate change and variability on offshore design criteria have been presented at 7th International Workshop on Wave Hindcasting and Forecasting, co-sponsored by PERD POL 1.2.1;

- 2004/05- Non-technical summary report for policy makers on storm trends, their impacts on design criteria, and their expected vulnerability to climate change;

- Journal articles on future extreme wave climate projections based on GCM model predictions for the 21st century, and innovative new extremal analysis techniques; invited paper on historical global wave variability at WMO CLIMAR-II conference.

This is a relatively small project, whose initial objective was to investigate historical observed and hindcast wind and wave data bases, homogenize them where necessary and feasible, carry out statistical analysis to determine climate trend and variability, and translate those results into potential impacts on future design criteria. Due to additional levering of Departmental resources, and important partnerships such as those with KNMI, the project has produced much more than expected, including global analyses rather than merely regional, analysis of multiple climate scenarios to the year 2100, a detailed time slice analysis of future climates, and ground breaking research on non-stationary extremal analysis and applying these innovative techniques to project possible future changes in climate extremes and hence design criteria. The results will be reported in scientific journals, technical workshops, industry forums, and international reports (World Meteorological Organization).

Funding

The average resources allocated for this project per fiscal year were $194,000 (2001-2002; 2002-2003). An average 29.1% of these resources came from PERD funds, the rest came from other sources (A-Base, industry, others such as Netherlands Met. Inst., US Army). The average leverage quotient of total resources to PERD resources for the project was 3.4.

Impacts of Evolving Ice Conditions on the Energy Sector

Project Manager: Tom Agnew

Project Objectives
This project does not stem from a previous PERD project. The work is part of the Climate Change Modeling and Impacts within MSC. The main objective of this project is to provide detailed assessment and interpretation of recent sea ice cover trends over Canadian marine areas of importance to hydrocarbon development and transportation and to provide guidance to the oil and gas industry on the implications of these trends.

This project benefits EC since it contributes to understanding regional changes in climate and potential impacts on the petroleum and transportation industry in northern Canada.

Methodology
The objective of this project will be reached by:

- Documenting and evaluating a new regional sea ice data dataset to determine how regional sea ice trends in Canada differ from sea ice trends in other circumpolar countries;
- Developing a regional arctic climate model of Canadian Arctic Islands, Hudson Bay and Eastern Canada.

Goals, Outputs and Project Success Story
A report has been prepared on the evaluation of the CIS ice charts database comparing it to the most widely accepted international satellite dataset of sea ice extent.

The work accomplished by this project has led to a publication comparing the ice chart data to satellite data published in the journal Atmosphere-Ocean.

Funding
The average resources allocated for this project per fiscal year were $198,000 (2001-2002; 2002-2003). An average 54.6% of these resources came from PERD funds, the rest came from other sources (A-Base). The average leverage quotient of total resources to PERD resources for the project was 1.8.

Critical Aspects of Changes in Sea Ice Cover on Energy Production

Project Managers: Tom Carrières and Tom Agnew

Project Objectives

This project follows some of the directions of a project that focused on digitizing CIS ice charts to provide data on sea ice trends in Canada. *Critical Aspects of Changes in Sea Ice Cover on Energy Production* will be moving to POL 1.2.3 Marine Transportation and Safety in 2004. The project is part of a loose collaboration with the project managed by Tom Agnew *Impacts of Evolving Ice conditions on the Energy Sector.*

The main objective of this project is to provide an indication of how sea ice conditions will evolve over the next 25 years.

This research assists CIS by providing us with information we can share with our clients. It also provides us with models that can be used to support our sea ice operations.

Methodology

The project downscales GCM results to the regional scale in order to have a better picture of how sea ice will evolve. The main emphasis is on determining how to downscale GCM forcing, to develop higher resolution coupled ice-ocean models and to develop techniques to interpret huge volumes of data.

Goals, Outputs and Project Success Story

The main output of this project will be a report that attempts to indicate how sea ice conditions will evolve over the next 25 years. Secondary results will be journal publications, conference presentations and finally coupled ice-ocean models that will be implemented at CIS. The project is on target and will conclude this segment on time.

The greatest success of the project is to bring together the experts and expertise required to run the project. A scientific steering committee comprised of people from different components of MSC and DFO labs met twice a year and resolved many technical issues. The other significant success is that the results from this project will provide the necessary input to follow-on projects funded through CCAF.

Funding

The average resources allocated for this project per fiscal year were $64,000 (2001-2002; 2002-2003). An average 84.4% of these resources came from PERD funds, the rest came from other sources (A-Base). The average leverage quotient of total resources to PERD resources for the project was 1.2.

Canadian Participation in FIRE III/SHEBA

Project Manager: George Isaac

Project Objectives

A previous PERD project on this topic was funded from 1996 to 2001. It covered the field phase for the Canadian participation in FIREIII or the FIRE Arctic Cloud Experiment (FIRE.ACE) as it became to be known. This project was part of a larger U.S. led project which combined both the FIRE.ACE project (NASA based) and the SHEBA project (NSF based).

This work will enable us to better understand Climate Change in the Arctic Environment where climate feedback effects and temperature changes are predicted to be the largest (Boer et al., 1992), and where little information is presently available. Also, as stated by Randall et al (1998), the larger uncertainty in the climate simulations occurs due to unsolved problems regarding to the physical and microphysical processes that occur in Arctic stratiform clouds.

This project has provided access to a large U.S. funded climate change project and ultimately better policy advice for Canada on climate change.

Methodology

The Canadian component of FIRE.ACE was to fund aircraft flights over the SHEBA ground site locked into the Arctic ice pack. An NRC Convair 580 was used for this purpose and it was extensively instrumented by the Meteorological Service of Canada for making cloud microphysical and air quality measurements. The subsequent data has been used to develop parameterizations for climate and weather forecasting models, and to verify those models in the Arctic environment.

Goals, Outputs and Project Success Story

Papers have been written for the special Journal of Geophysical Research (JGR) issues on FIRE and SHEBA. Several journal papers have already been accepted to Geophysical Research Letters, Meteorology and Atmospheric Physics, the Journal of Climate, the International Journal of Climate, Annalen Geophysica, and the Quarterly Journal of the Royal Meteorological Society. The data set is being actively used by many individuals doing studies on better parameterizations of clouds and aerosols within Climate Models and Weather Forecasting Models and work have been presented at several international meetings,

Even after PERD funding ended, the data set is being used by many Canadian and U.S. researchers trying to better understand the role of Arctic clouds in our climate system. During course of the project, 17 journal articles (see item 8) and over 32 conference presentations were produced.

Funding

The average resources allocated for this project per fiscal year were $323,000 (2001-2002; 2002-2003). An average 35.0% of these resources came from PERD funds, the rest came from other sources (A-Base and others). The average leverage quotient of total resources to PERD resources for the project was 2.9.

Profiles by Strategic Intent

Climate Sector

Impacts of Climate Change on the Energy Sector

FIRE III/SHEBA

Climate Change Impacts on Cold-Regions Hydrologic Processes and Extreme Events Associated with the Hydro-Electric and Oil/Gas Industries in Western and Northern Canada

Project Managers: Terry Prowse and Philip Marsh

Project Objectives

The original PERD project was only initiated with funding in July 1999 and was merged with another study by P. Marsh into the new 2001 PERD POL program. Some of the objectives (e.g., glacier resources) from this 1999-2000 project were not undertaken because the project was only funded at 27% of the request level. Furthermore, they do not form part of the 2001 POL PERD program which has been expanded to include impacts on the energy sector (oil and gas: Mackenzie Delta and arctic lake/river ice) in Arctic Canada. This project stems from work conducted as part of the EC Northern Rivers Basin Study (NRBS) and the subsequent EC Northern Rivers Ecosystem Initiative (NREI). It also has strong links with the Climate Change Action Fund (CCAF) projects, Polar Continental Shelf Project (PCSP) and the Canadian Foundation for Climate and Atmospheric Sciences (CFCAS). Collaborative work also ensued with DIAND Water Resources Division in Yellowknife.

The objectives of the proposed work are to improve our understanding of the climatological and hydrological factors that affect energy production and transmission, particularly hydro-electric power in western Canada, and oil and gas development in northwestern Canada. Through a climate model based approach, this study quantifed the effects of a changing climate, particularly extreme hydrological events and changes in permafrost, on energy production and transmission. As well initial steps were taken with respect to adaptation to climate change through the development of an operating strategy for hydro-electric facilities under future climate-change conditions to control downstream extreme events and minimize water-resource conflicts.

This study builds on EC's research into the effects of climate change on hydrology and aquatic ecosystems, a major research project of the National Water Research Institute (NWRI). By linking with the hydro-electric industry and oil/gas development, it also creates unique adaptation strategies whereby the effects of climate change might be reduced on vulnerable ecosystems. This work falls within EC's accountability framework that builds the climate-change ecosystem impact case for the Nature result which deals with impacts on the health of ecosystems (e.g. understanding and reversing habitat loss) and ensures that priority ecosystems are conserved and restored. More specifically, this project falls within NWRI's Aquatic Ecosystem Impacts Research Branch (AEIRB) which is in turn part of the Environmental Conservation Service (ECS) of EC.

Methodology

The research fell under three broad project components:

- Changes to western Canada snow and ice resources re: hydro-electric industry: A Microsoft Access snow depth and snow water equivalent (SWE) database was previously created for western Canada. Updates have been made to

- include stations with long-term records that can be used for trend analysis of snow conditions over the cordillera. Temperature, hydrometric and hydrocryospheric data were interpreted to determine mid-winter warming events and their impacts on river ice regimes. Global Climate Models (GCMs) were used to evaluate current and future climate periods.

- The Snowmelt Runoff Model (SRM) was used for predicting future changes in snow cover using GCM temperature and precipitation values as input.

- Simulations with the WATFLOOD distributed hydrological model were performed on a total of 16 long-term flow-gauging stations within the Peace River Basin; and

- An empirical methodology was developed to assess climate impacts on the frequency and severity of ice-jam flood events on hydro-electric regulated rivers.

- Freshwater ice changes re: oil and gas exploration/development:
  Evaluation of GCM outputs for replication of northern climatic conditions continued and the development of a suite of future temperature and precipitation scenarios for northern Canada based on GCM output ensued. Also, evaluating the implementation of an ice growth model for application in northern latitudes and current theories regarding the bearing strength of ice for transportation continued.

- High-Latitutde hydrologic changes re: oil and gas exploration/development:
  Evaluation of high-latitude hydrologic changes from past changes in climate and hydrology, validation of existing hydrologic models (including WATFLOOD), utilization of solar radiation and wind flow models, testing WatClass (a modified version of the Canadian Land Surface Scheme (CLASS)) and consideration of the factors controlling the stability of permafrost dammed lakes and the relationship to climate carried through.

Goals, Outputs and Project Success Story

Improving our understanding of the climatological and hydrological factors that affect energy production and transmission, particularly hydro-electric power in western Canada:

Historical changes to regional distribution of alpine snow and ice resources were analyzed for trends and variability in monthly (October to April) snow depth values for the periods 1915-1999 (19 stations) and 1950-1999 (62 stations). Mid-winter warming events and associated hydrologic pulse events that can induce river ice-jam events and thus adversely affect hydro-electric production were examined. The 1961-1990 climatological values of monthly mean temperature and total precipitation from seven GCMs (recommended by the IPCC) were assessed in their ability to replicate current observed climate over the western cordillera of Canada; and, four of the seven GCMs were chosen for future climate scenarios over the western cordillera for:

- two different greenhouse-gas emission scenarios for the 30-year periods centred on the 2050s and the 2080s.

- SRM simulations estimating changes in snowcover for three elevation bands, indicated that the upper elevation bands would be removed by approximately 20 days earlier than under present conditions; and, the lower elevation band snow would only cover 10% of the area at the end of March in the future compared to 70% under present conditions.

- WATFLOOD model calibration for the period 1961-90 continued and predictions for future climate impact in this region resulted in hydrographs showing a substantial reduction in flow, particularly during the spring period. Although changes in temperature and precipitation were applied uniformly across the entire Peace-Athabasca basin, sub-basin response were not uniform. This leads us to conclude that certain regions in the basin may be more sensitive to average changes in precipitation and temperature than others. Simulated inflows into the Williston reservoir were also extracted and results from the 5 GCMs used in this analysis indicated a reduction between 20 to 40 percent. The SRM also allows for estimation of runoff from alpine areas. Its application in the Liard River basin will complement the more detailed modeling schemes being applied to other areas of the Western Cordillera.

- Using air temperature and precipitation from CGCM1 (Canadian General Circulation Model version 1), it was determined that for the period centering on the 2080s, that the frequency of ice-jam floods would be further reduced mainly because of reduced snowpack. Under this scenario no attempt was made to calculate snowpack reductions due to mid-winter melt. An update of this analysis under more advanced GCM predictions (i.e. CGCM2) is underway. Having established the hydro-climatic conditions leading to ice-jam flooding, and with a preliminary indication as to future hydro-climatic conditions, we can now begin to investigate options for regulation strategies that will address the dual objective of maximizing hydro-electric production under future climate-change conditions and minimizing downstream hydrologic impacts.

Improving our understanding of the climatological and hydrological factors that affect energy production and transmission with regards to oil and gas development in northwestern Canada:

16 future GCM scenarios of daily temperature and precipitation for 40 Arctic stations were assessed for a range of potential future changes to freshwater ice regimes in various regions within northern Canada. A temperature-index model allowed for an initial assessment using only temperature and precipitation parameters provided by the GCMs. The Canadian Lake Ice Model (CLIMo) was also further validated for northern conditions using hydro-climatic data from Baker Lake, Nunavut. Since this model is more physically based and such outputs as relative humidity and cloud cover have not yet been evaluated from the GCMs, the focus will be more on index modeling for future climate-change based predictions. Some progress was also made on incorporating white-ice formation algorithms into the

- temperature-index model, thus allowing to model changes in cover composition and not just thickness.

- We have carried out a synthesis of past changes in hydrologic regime in northwestern Canada (Marsh *et al.*, in press), and validated models for predicting changes in the hydrologic regime in the northern Mackenzie region. Initial model validation, using Watflood is complete, as are validation studies using two wind flow models, and a radiation model. Additional studies applying WATCLASS to the Inuvik research basins is well underway and will be published this year. In addition, work suggests that the rate of lake drainage is related to climate, with increased drainage in the Richards Island and Tuktoyaktuk Peninsula, where gas development is proposed, would be expected to have much larger discharge during rapid drainage. The issue of rapid lake drainage has two components. First it is possible that gas development and production could increase the rate of lake drainage through disturbance of the active layer, and second, rapid lake drainage could have significant effects on pipelines through much larger discharge than expected. In addition, since lake drainage may not occur through the regular channel outlet, rapid drainage can result in the creation of new channels that can be in the order of 10 m wide and 5 m deep. Ongoing work suggests that the rate of lake drainage would increase under a warmer and wetter climate.

Examples of project successes include:

- As described in Prowse *et al.* (2002d), recent research has found that most of the ecologically important floods affecting the Peace-Athabasca Delta (PAD) are produced by spring ice jams. Spring flow-release strategies of the upstream hydro-electric reservoir were modified to increase the probability of ice-jam flooding near the PAD employing non-structural measures. Favorable conditions in the spring of 1996 were prevalent allowing flooding, and the PAD experienced its first major flood in over 20 years. This has been identified as an adaptation measure whereby regulated rivers can be 'modified' to ameliorate some negative effects of climate change.

- Work has demonstrated ongoing changes to climate in the lower Mackenzie, with spring breakup for example occurring much earlier in the spring.

- Preliminary work has provided the first documented description of the processes and maximum flow rates occurring from permafrost dammed lakes.

Funding

The average resources allocated for this project per fiscal year were $801,000 (2001-2002; 2002-2003). An average 15.4% of these resources came from PERD funds, the rest came from other sources (A-Base and others such as NREI, CCAF II, PCSP, NEI, CFCAS, DIAND/INAC). The average leverage quotient of total resources to PERD resources for the project was 6.5.

Profiles by Strategic Intent

Climate Sector

Impacts of Climate Change on the Energy Sector

Climate of Western Canada

Critical Aspects of the Climate of Western Canada for the Energy Industry

Project Manager: Kit Szeto

Project Objectives

This project does not stem from a previous PERD project. Part of the work for this project is closely related to the research of the Mackenzie GEWEX Study (MAGS) research network (NSERC and EC supported). The objective of this work is to provide detailed assessments and interpretations of our capabilities to simulate climatic conditions (including precipitation, clouds and temperature) over several areas of western Canada (including much of the Prairies and the Mackenzie basin) of importance to the energy industry and to provide guidance to the energy industry of the implications of the findings.

This project contributes to EC climate change objectives by enhancing our knowledge of the water and energy cycles in western Canadian regions, and the application of the improved knowledge to assess the current capability, and to provide recommendations for the future improvement, of our regional climate model.

Methodology

This project addresses major issues of concern to the energy industry over parts of western Canada. Global climate models are essentially unanimous in their predictions for this region: higher temperatures, less but changing patterns of precipitation, and probably more 'extreme events'. Critical questions to be considered include: will such conditions actually occur and how does this affect the energy industry? The key to addressing these questions include enhancing our understanding of the processes that are responsible for the climate variability and extremes for the region, as well as critically assessing the accuracy of current climate models in representing these climate processes when they are used to simulate past climate conditions.

The water and energy budgets for regions of western Canada were calculated from several independent climate datasets (including operational observations, assimilated datasets from different centers and remote-sensing data). This dataset serves as a baseline dataset for studying the water and energy cycle for the region as well as a validation dataset for regional climate models. The climate processes responsible for the variability and extremes of climate conditions for the regions were studied by examining the budgets for anomalous periods (e.g. anomalously warm winters, summer drought, etc.). Climate simulations using the latest (third) version of the Canadian Regional Climate Model (CRCM III) were performed and validated against the water and energy budget dataset. A rigorous evaluation of several parameters of interest to hydroelectric and renewable energy (wind, solar) energy clients was conducted. These parameters include precipitation, evaporation, temperature, wind and cloudiness.

Results of this effort are a quantitative assessment of the degree to which our regional climate model represents the regional water and energy cycle under different conditions. This assessment will then be used to assist the evaluation of aspects of climate scenarios (and in turn climate impacts studies) of importance to hydroelectric and renewable energy interests in the Prairies.

Goals, Outputs and Project Success Story

The goals of the project include:

- The development of a comprehensive water and energy budget estimates for regions of western Canada;
- Enhancing our understanding of processes governing the climate variability and extremes for the region; and
- Assessing the accuracy of current climate models in simulating past climate conditions for the region, and make use of this knowledge to make recommendations for future improvements of climate models, and to help the energy sector in the interpretation of climate change scenario.

Status and outputs of the project include:

- The development of a comprehensive baseline estimate of the water and energy budgets for the Mackenzie Basin;
- Multi-year CRCM simulations of climate conditions for western Canada;
- An improved understanding of processes governing the climate variability and extremes for the Mackenzie Basin and the Prairies;
- Critical validations of the CRCM simulations with the dataset developed and the use of the improved knowledge developed to diagnose the reasons for short-comings in the model results; and
- Conference/workshop presentations and publications documenting the scientific results from this work.

In the coming year, the water and energy budget calculations will be extended to the Canadian Prairies. We will examine the processes that are important in the development of drought for the region, as well as critically assess how well the CRCM can simulate these conditions.

Through the work in this project, we identified serious short-comings in our CRCM simulations of climate conditions for western Canada. Through the enhanced understanding of processes governing the climate of western Canada that are developed in this research, we were able to diagnose the causes of these short-comings in the model. We are thus able to make specific recommendations on how to significantly improve our future models and their climate change projections, especially for regions that are of particularly importance to the energy industry in Canada, such as the Mackenzie Basin and the Canadian Prairies.

Profiles by Strategic Intent

Climate Sector

Impacts of Climate Change on the Energy Sector

Climate of Western Canada

In addition, the work of this project contributes significantly to the objectives of both the MAGS project, as well as international GEWEX (Global Energy and Water cycle Experiment), through the development of the comprehensive water and energy budget estimates for the Mackenzie Basin, and through the elucidation of physical processes that govern the climate of northern continental regions.

Funding

The average resources allocated for this project per fiscal year were $150,000 (2001-2002; 2002-2003). An average 50% of these resources came from PERD funds, the rest came from other sources (A-Base). The average leverage quotient of total resources to PERD resources for the project was 2.0.

Snow Water Equivalent Variations in Western Canada and Climate Change Related Impacts for Hydropower Production

Project Manager: Anne Walker

Project Objectives

This project does not stem from a previous PERD project. The current work complements similar research that is being conducted by CRB in the Mackenzie GEWEX Study (MAGS) and the associated scientific collaborations and leveraging. The project also complements CRB satellite snow cover algorithm research that is being conducted within the Canadian EOS project CRYSYS (Variability and Change in the Cryospheric System in Canada). Field data collection campaigns in support of this PERD project are being coordinated with field studies and campaigns that are planned within the CRYSYS project.

The objectives of this project are:

- To create a 20-year time series (1979-1999) of satellite-derived snow water equivalent over selected basins in western Canada that are of key importance to hydropower production;
- Analyze the spatial and temporal variations in snow water equivalent depicted in the time series and determine the vulnerability of hydropower facilities during the 20 year period to provide a baseline for future expected changes;
- Using future climate scenarios based on output from the Canadian global climate model (GCM), develop scenarios of change in SWE and assess the expected impacts of these changes on hydropower operations over the next 50-100 years, and;
- Conduct a preliminary assessment of the feasibility of incorporating satellite-derived SWE into regional climate modeling.

This project benefits EC because it enhances our understanding of the climate system and improves our ability to forecast future climate, as well as establishing close collaboration between major energy generating companies and EC.

Methodology

The work that is being conducted within this PERD investigation can be summarized as follows:

- Generate a validated 20 year SWE time series at a 25 km spatial resolution for western Canada using Nimbus-7 SMMR and DMSP SSM/I satellite microwave radiometer data sets covering the period 1979-2003;

Examine the temporal and spatial variations in derived SWE over the 20 year time series for selected basins of interest to hydroelectric power companies in western Canada (i.e., Manitoba Hydro and NWT Power); produce a report documenting the

- associated impacts and vulnerabilities of hydropower production with respect to these variations ;
- Compare the spatial and temporal SWE patterns/trends over the 20 year time series to temperature and precipitation data sets and assess relationships between derived SWE and these climate elements; produce a report documenting the 20 year time series as a "baseline" climate;
- Examine climate scenarios (based on global climate model output) for the next 50-100 years for predicted changes in temperature and precipitation over western Canada and determine potential changes in snow cover and SWE over the region for the same time period; produce a report outlining expected impacts of the changes in SWE on hydropower operations over the next 50-100 years;
- Conduct a preliminary investigation of potential enhancements of SWE retrievals from EOS Aqua AMSR data and potential use of satellite derived SWE in hydrological and climate (global and regional) modelling for model validation/initialization; prepare a report documenting results of this investigation.

Goals, Outputs and Project Success Story

The major activity for this year has been the planning and execution of a snow cover field validation campaign focussed on the verification of a high SWE zone (SWE > 100 mm) that appears consistently each winter season in northern Manitoba between Gillam and Churchill. Since snow cover measurements are not routinely conducted in this region, this field campaign was considered essential to provide valuable information on the snow cover characteristics in northern Manitoba and provide the means to evaluate the passive microwave satellite SWE retrievals. This is a necessary step before continuing with the analysis of the temporal and spatial variations in SWE depicted in the 25-year historical data set. Since Manitoba Hydro is interested in knowing snow cover amounts in this part of Manitoba for managing hydropower operations, they have been collaborating with CRB in the planning and execution of this field campaign by providing logistics and manpower support from their Thompson, Manitoba office. At the end of November 2003, ground-based (by road vehicle) and helicopter-based (helicopter time donated by Manitoba Hydro) snow surveys were conducted from Thompson to Gillam (by road) and from Gillam to Churchill (by helicopter) to acquire measurements of early winter snow conditions. A second field campaign is currently underway with a focus on maximum winter season snow cover conditions.

In January 2004, transitional funding for 2004/05 was awarded for this project in order to complete the remaining objectives: Report on SWE time series analysis as a "baseline study"; report on expected impacts of the changes in SWE on hydropower operations over the next 50-100 years; report on preliminary investigation of potential enhancements of SWE retrievals from AMSR data and potential use of satellite derived SWE in hydrological and regional climate modelling.

A major success from this project is the enhanced collaborative relationship that has developed with Manitoba Hydro. Manitoba Hydro is quite pleased with the work that we are doing to derive information from the passive microwave satellite data on SWE conditions in this region -- the SWE maps that we provide them with in near real time during the winter have become an essential information source for their operations. They have been eager to collaborate with us in whatever way they can to help validate and improve our techniques. They were active participants in the planning and execution of our snow cover field measurement campaign in Northern Manitoba this past winter, providing both manpower and helicopter time to support the field data collection activities.

Funding

The average resources allocated for this project per fiscal year were $115,000 (2001-2002; 2002-2003). An average 26.1% of these resources came from PERD funds, the rest came from other sources (A-Base). The average leverage quotient of total resources to PERD resources for the project was 3.8.

Changes in Cloud Cover over North America for Solar Energy Development in Canada

Project Manager: Sunling Gong

Project Objectives

This project does not stem from a previous PERD project and is not part of a bigger project. The main objective of the work is to provide information on the impacts of climate change on the availability of solar energy in Canada. Specific sub-objectives are:

- Establish the scientific tools to study the impact of cloud changes on the solar energy availability across Canada under various climate change scenarios;
- Investigate the current cloud cover patterns and trends over Canada for the future climates under various emission scenarios;
- Study the impacts of climate change on the availability of solar energy in Canada using the tool developed by taking into account more detailed emission information in Canada;
- Improve the high-resolution regional cloud mechanism in the NARCM (Northern Aerosol Regional Climate Model) in order to reasonably forecast cloud cover patterns in the North American continent.

Social adaptation to a changing environment can be difficult and costly, so some ways must be found to minimize the adverse effects of human activities on the environment and hence on resources. This project, by providing some results simulated by a Regional Climate Model (RCM) for cloud cover, surface solar radiation as well as precipitation of the 1990s and 2080s in North America, gives a map of how the main climate elements change in the last decade and in the future. These efforts, by cooperating with industry, would be a scientific basis for the future solar energy development in Canada. Meanwhile, EC would get credit and funds support from industry to do continued research into climate change and trends.

Methodology

Among all atmospheric parameters, cloud cover is the dominant factor for determining the solar radiation reaching at the earth surface. Therefore, it is necessary to investigate the changes in cloud cover associated with the global climate change, especially in Canada, and how such cloud cover changes interact with the change in climate. A previous PERD project on anthropogenic aerosol and climate, has resulted in a significant improvement in simulation of aerosol and cloud in Canadian climate models (GCM and NARCM), by including a size-segregated multi-component aerosol module CAM (Canadian Aerosol Module). The present research proposes to apply the previous research results on aerosol and clouds to study the regional cloud coverage patterns in North America and to estimate the impact of cloud changes due to the global climate changes on the solar energy production industry in Canada. The project can be divided into the following several parts:

- Collection of observed data/reanalysis data:

- Cloud cover observation data: The data is product of ISCCP (International Satellite Cloud Climate Program). It includes 10-years global cloud cover data in 1990s on a monthly time scale with a resolution of about 2.5 latitude by 2.5 longitude. This data will be analyzed to investigate the cloud cover change trend and pattern in North America, especially in Canada, during that decade and be used to compare with NARCM simulation.

- Precipitation data: monthly averaged precipitation data which merges gauge, 5 kinds of satellite estimates (GPI, OPI, SSM/I scattering, SSM/I emission and MSU) and numerical model predictions during 1990s.

- The surface solar radiation flux data between 1990 to 1995 (in W/m^2) is calculated by using a complete radiative transfer model and observations of the physical properties of the surface on ISCCP data sets.

- NCEP Reanalysis surface temperature data is provided by the NOAA-CIRES Climate Diagnostics Center, Boulder, Colorado, U.S.A., from their Web site at http://www.cdc.noaa.gov.

- Model simulations for present climate and comparison with observation: NCAR/NCEP reanalysis data as lateral boundary condition, the high-resolution regional climate model, NARCM, with/without size-distributed aerosols module have been run for 1990s to test the model and to provide a preliminary image of the spatial and temporal distribution of current cloud coverage in North America. Our emphasis is placed on the aerosol-cloud interaction processes. The results had been compared with the observation data in different climate regions in North America to test, and finally improve the simulation and prediction of the regional climate model. On the basis of all these experiments and analyses, the scientific tools for studying the impact of cloud changes on the solar energy availability in Canada under various climate change scenarios has been basically established.

- Climate simulation for 2080s:
  The reliable projections of future emissions are very important to reliable predictions of future climates. The tools of climate models are used with future scenarios of forcing agents (e.g., greenhouse gases and aerosols) as input to make a suite of projected future climate changes that illustrates the possibilities that could lie ahead. In this part, NARCM, driven by the results of Climate System Model (CSM) of NCAR, is selected to run for 7 years during 2080s under IPCC SRES A1 scenario. The A1 scenario family describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. This numerical experiment scheme is designed to address the issue how the climate elements will change in 2080s.

Goals, Outputs and Project Success Story

- NARCM (Northern Aerosols Regional Climate Model) has been used to simulate the cloud cover, surface solar radiation, precipitation and surface temperature in North America from 1990 to 1995. Two 6-year simulations, with aerosols and without aerosols, are evaluated and compared with observed spatial pattern and regional mean. The results indicate that NARCM correctly captures the overall observed patterns and magnitude of cloud cover and surface solar radiation over most regions of North America. As compared to the original RCM without interactive aerosols, some apparent improvements are achieved with a better simulation of the high-latitude cloudiness, area-averaged cloudiness and surface solar radiation. The model is also found to reasonably depict the precipitation and surface temperature distributions.

- On the basis of the present climate simulation, NARCM is integrated for 7 years in 2080s under IPCC SRES A1 scenario. Compared with the simulation of 1990s, the simulation for 2080s shows some different features in the climate elements mentioned above, such as high latitude warming especially in northeast of Canada and Greenland, as well as decreasing precipitation in most parts of Canada.

All simulations about this project have been done. The paper about present climate simulation has been written and will be submitted to a journal in the near future. The paper about future climate change is in process and finished very soon.

For the present climate, two model versions ONN (with aerosols) and OFFN (without aerosols) had been used to simulate the main climate elements, such as cloudiness, surface solar radiation and precipitation. It is very obvious that ONN gives a better description of cloud cover in North America. This suggests that:

- Anthropogenic aerosols have obvious impacts on climate change;

- Climate models should take the aerosols radiative effect into account, especially in long term climate simulation.

According to the simulation for present climate:

- Cloud cover changes relatively little with an increase in land areas (especially in west USA and high latitude) and a decrease in oceans;

- Surface solar radiation (SSR) increases in most parts of Canada and south central USA; SSR decreases in east coast of USA, Greenland, west coast of North America, especially in west coast of USA.;

- Surface air temperature (SAT) increases in Greenland and most part of Canada, especially in Northeast of Canada. This result is consistent with GCMs simulation; SAT decreases in other areas especially in whole USA with an exception in south central USA;

- Most parts of Canada would experience a decreasing precipitation in 2080s; Greenland, West and East of USA would get more precipitation in 2080s.

Funding

The average resources allocated for this project per fiscal year were $182,000 (2001-2002; 2002-2003). An average 56.0% of these resources came from PERD funds, the rest came from other sources (A-Base). The average leverage quotient of total resources to PERD resources for the project was 1.8.

Climate and Energy in the Toronto-Niagara Region (Integration of Science and Policy)

Project Manager: Brad Bass, Heather Auld and Joan Klaassen

Project Objectives

This project stems from a previous PERD project looking at the impacts of climate change on the energy sector in the Toronto-Niagara Region. This work is one contribution to a larger study on the impacts of climate change in the Toronto-Niagara Region. The larger project is also under the direction of AIRG and the project lead is Brian Mills. The work is also part of a larger MSC-Ontario Region study on atmospheric and climatic hazards, critical infrastructure and climate change, led by Joan Klaassen. This has included previous work on natural gas energy demand and winter climate variability and change, electrical demand and summer climate variability and change, IJC sponsored studies on hydroelectricity potential on Lake Ontario and climate variability and change and risks to transmission and electrical distribution lines.There were 6 related sub-objectives of the proposed work:

- To assess the vulnerability of the energy sector (production, transmission and demand) in the Toronto-Niagara Region to climate variability and extreme weather;
- To assess the impacts of climate change on the energy fuel cycle (generation, transmission, and demand) in the Toronto-Niagara Region, in consultation with stakeholders;
- To create regional climate change scenarios for the Toronto-Niagara Region;
- To assess changes in the energy sector that are driven by emissions policies (e.g. deregulation, air quality, Canada Wide Standards, climate change policies) and the vulnerability of a changing system to the impacts of a climate change;
- To assess, in a preliminary manner, the relative abatement costs and ancillary benefits of GHG plus related emission reductions in the energy sector for the Toronto-Niagara Region; and
- To communicate scientific and technical information on the climate – energy relationship to regional stakeholders and policy makers, and engage them in formulating a plan for a sustainable energy system in the Toronto-Niagara Region.

This project benefits EC by:

- Assisting EC in helping the relevant make better decisions with regard to energy for the future;

- Raising profile of EC with energy sector stakeholders and with PERD;
- Developing new partnerships between EC, industry, NGOs and academia;
- Developing new tools for EC to use in other research;
- Developing new results for publication to raise profile of EC research in academic community;
- Providing baseline research for the development of tools to better predict severe ice storms (peer-reviewed paper pending in Weather and Forecasting journal);
- Contributing valuable information for all municipalities in Ontario in planning emergency response and management under legislated requirements for the Ontario Emergency Management Act (2003);
- Enhancing relationships and credibility between EC, federal government and province of Ontario;
- Contributes to EC-Ontario Region Clean Air and Climate Change Strategy;
- Contributes information for the Canada-US Border Airshed Management Study.

Methodology

Objectives and goals of this project will be achieved by:

- Synoptic climatology to develop scenarios, development of downscaling methodology for extreme precipitation events, refinement of synoptic map typing methodologies to include interpolated higher atmosphere fields;
- Consultation with stakeholders;
- Construction of optimization model to assess the integrated effect of policy and climate change on the energy sector under different GHG emission targets.

Goals, Outputs and Project Success Story

The work on the scenarios is largely completed. We are moving towards a stakeholder workshop to share and validate the results and to identify remaining gaps to address in the final year. The workshop will highlight the following research:

- Impact of climate change on the generation, transmission and distribution;
- Impact of freezing rain on distribution infrastructure, including transmission;
- Impact of emissions on health;

- The Canadian Regional Energy Model;
- Temperature-Energy Demand curves for climate change;
- The impact of climate change and emissions policies on the energy sector.

The project's successes include:

- The Canadian Regional Energy Mode;
- Input to Ontario Region Clean Air and Climate Change Strategy, to Canada-US Border Airshed Management Study;
- New tools for weather prediction and warning of severe ice storms;
- Essential information on severe ice storm risks for use by municipalities in meeting legislated requirements of the Ontario Emergency Management Act (2003);
- New partnerships;
- Collaboration between MSC and Ontario Region and municipalities;
- Recognition from PERD of the quality of the work and the process of involving stakeholders.

Funding
The average resources allocated for this project per fiscal year were $119,000 (2001-2002; 2002-2003). An average 66.4% of these resources came from PERD funds, the rest came from other sources (A-Base and others). The average leverage quotient of total resources to PERD resources for the project was 1.5.

Profiles by Strategic Intent

Climate Sector

Steps to Increase the Net GHG Uptake

Strategic Intent 6 · Strategic Direction 2

Strategic Direction 2 is to provide S&T to enhance the natural uptake of GHG's from the atmosphere. More specifically, the program will address:

Strategic Intent 6 · Strategic Direction 2 · Objective 6.2.1

The Development of a Better Understanding of the Relevant Natural GHG Cycles; and Steps to Increase the Net GHG Uptake from the Atmosphere by Forests, Agricultural Lands and Oceans.

POL 6.2.1—Enhancement of Greenhouse Gas Sinks (EGGS)

As part of our effort to avert the negative consequences of climate change we must improve our knowledge of how CO_2 emissions cycle in the environment. Because the natural cycle of carbon and nitrogen that control the release and uptake of GHGs are complex, increased understanding of the carbon sink phenomenon will be a step in that direction. The concept of the carbon sink evolved, in the environmental community, hand in hand with the awareness of GHG emissions and their impact on the climate. The carbon sink concept describes the ability of a number of natural processes active in forests, soils, and oceans, to absorb and sequester CO_2. However, much more work is needed before verifiable reporting of greenhouse gas uptake through sinks projects will be achievable. The EGGS POL focuses on better understanding the natural processes governing sources and sinks of GHGs within Canada's natural and managed terrestrial ecosystems and adjacent ocean environments, by undertaking coordinated research efforts directed specifically at those aspects of the science relative to future reporting of sinks under the Kyoto Protocol. Many of the POL projects will be conducted collaboratively with the broader climate change research community.

A PERD project from EC that will supply some of the answers regarding natural carbon sinks, took place in Northern Ontario. The scientific staff engaged on this project collected CO_2 samples from ground level and airborne sources. The new data improved an existing model of the biospheric/atmospheric CO_2 exchange process. The updated model was then used to interpret six years of CO_2 concentration data from the locale, and to provide a map of the strength of the biospheric carbon flux over time. This is an important early step in understanding the flow of CO_2 between boreal forest ecosystems and the atmosphere. Another EC project looks into the susceptibility of forested wetlands carbon budgets to climate change and natural variability. The presence of a monitored watershed at Turkey Lakes has enabled the CFS to build upon a large database for use in modelling. The study determines the C stock in uplands/wetlands, partitioning between atmosphere and water to measure the response of wetland C stocks and fluxes to artificial wetland drying, and to explain the role of aquatic ecosystems in the carbon sink. This will contribute to the preparation of a carbon budget of forested wetlands and potential impacts of climate on carbon cycling.

The following activities are included under POL 6.2.1:

- Forest Sinks

Profiles by Strategic Intent

Climate Sector

Steps to Increase the Net GHG Uptake

- Agricultural Soil Sinks
- Ocean Sinks
- Hydro-electric Reservoirs
- Science Advisor on Climate Change

This POL is funded by the following federal departments: NRCan, EC and Fisheries and oceans and AAFC (Agriculture and Agri-Food Canada). Participating universities include BIOCAP, Göteborg University, Macmaster University, University of Alberta, Waterloo, Manitoba, Toronto and Saskatchewan as well as Michigan Technological University and Sault College. There are several partnerships with industry, such as Alberta Forest Products, Al-Pac, BC Hydro, Canadian Pulp & Paper, etc. A number of agencies are also involved in the POL's projects: US Department of Energy (USDOE), USDA Forest Service, Ducks Unlimited, CCAF, CCFIA, Canadian Space Agency, CFCAS and many more.

For 2001-2002 and 2002-2003, the POL plan included 5 sub-projects where each sub-project was divided into themes, each theme had a team of researchers from various departments that shared the resources allocated to that theme. The allocation to each researcher under each theme is considered as a project. Therefore, The total number of themes in the POL was 22, there were 8 EC researchers leading the sub-projects in 2002-2003. POL 6.2.1 is in its third year of a 5-year POL Plan.

The total 2001-2002 annual budget for POL 6.2.1 was $8,102,400 and $9,855,000 for 2002-2003. The total PERD resources available for 2001-2002 were $1,694,300 and for 2002-2003, $1,941,000. PERD funds were divided amongst the departments involved in this POL (see Table 17). For this POL, the leverage quotient of total resources to PERD resources for 2001-2002 was 4.8 and 5.1 for 2002-2003.

Table 17 Percentage of PERD Funds for POL 6.2.1 Allocated to Each Department

Department	Percentage of Funds (%)	
	2001–2002	2002–2003
NRCan/EC	39.5	34.5
DFO	27.9	37.0
AAFC/EC	26.4	23.0
EC	6.3	5.5

Profiles by Strategic Intent

Climate Sector

Steps to Increase the Net GHG Uptake

Terrestrial CO_2 Sources and Sinks

Environment Canada Projects for POL 6.2.1

Estimation of Terrestrial CO_2 Sources and Sinks in Canada

Project Manager: Kaz Higuchi

Project Objectives

This project is a follow up from a previous PERD project that focused on the development of a 3-dimensional atmospheric transport model for CO_2 coupled to an ecosystem model. The goal of the present PERD project is to obtain vertical aircraft profiles of CO_2 over the BERMS site during the growing season of each year, for validation of the model performance and improvements. In the preceding PERD project, we performed similar aircraft measurement campaigns over Fraserdale in northern Ontario. This project is conducted by the Air Quality Research Branch, MSC, in order to complement a collaborative CFCAS project with Professor Jing Chen of the University of Toronto.

The objective of the project is to carry out vertical aircraft profiling of atmospheric CO_2 over the BERMS site, to provide data to verify and constrain model calculations on net CO_2 flux from boreal ecosystem.

EC is the lead government agency in the implementation of and compliance to the terms of the Kyoto Protocol. In this context, IPCC has recommended an independent top-down approach in estimating net carbon flux. The top-down approach employs a 3-dimensional atmospheric transport model to interpret measured atmospheric CO_2 concentration in terms of temporal and spatial distributions of carbon sources and sinks over Canada. In order to verify the usefulness of the coupled atmosphere-biosphere model, we need to constrain (and improve) the model with vertical CO_2 concentration measurements. The PERD project is part of an overall strategy for EC to obtain a useful and relatively accurate tool for a top-down method.

Methodology

In the previous PERD project, we developed an aircraft sampling unit for in-situ measurements of meteorological and CO_2 concentration measurements, as well as flask sampling for CO_2 concentration and its stable isotopes. With the present level of PERD funding, we carry out a single 1-week aircraft measurement campaign in June or July of each year over the BERMS site in northern Saskatchewan.

Goals, Outputs and Project Success Story

During June 2003, we carried out 1-week aircraft measurement campaign over the BERMS site. Some preliminary analysis results were presented at the 12th WMO Meeting of CO_2 Experts in September, 2003 in Toronto. A more detailed analysis has been carried out on the data obtained during the 2002 campaign. Some highlights are given below.

During the fiscal year 2002-2003, we carried out one aircraft measurement campaign over the BERMS site in northern Saskatchewan during the period 8-12 July 2002, to obtain in-situ vertical profiles of CO_2 and meteorological parameters (temperature, pressure, moisture, wind). We also obtained approximately 60 flask samples for concentration analyses of CO_2, CH_4, N_2O, and CO, as well as for stable isotopes $\delta^{13}C$

and $\delta^{18}O$ of CO_2. We were also able to obtain low-level in-situ atmospheric CO_2 measurements from Toronto to Prince Albert.

During the July 2002 aircraft campaign at BERMS, there was a passage of a weak warm front on July 10. It is interesting to note that the concentration of CO_2 in the planetary boundary layer increased by about 5 ppm in the air mass behind the warm front. Also, under "normal" conditions, $\delta^{13}C$ and $\delta^{18}O$ are correlated, but the vertical profiles taken during these 2 days indicate an anti-correlation.

The fiscal year 2004-05 is the last year of the PERD project. We will carry out another 1-week aircraft measurement campaign in June 2004.

An internal report summarizing all the aircraft data will be published by the end of March 2004. A scientific paper on the interpretation of the aircraft data will be submitted to a peer-reviewed journal by early summer of 2004.

Funding

The average resources allocated for this project per fiscal year were $22,000 (2001-2002; 2002-2003). An average 86.4% of these resources came from PERD funds, the rest came from other sources (A-Base). The average leverage quotient of total resources to PERD resources for the project was 1.2.

Wetlands in the Forest Context-Carbon Sink Potential

Project Manager: Rick Bourbonnière

Project Objectives

The wetlands related sinks research began under the "new" PERD structure. Our work is linked within the POL 6.2.1 structure to all of the other forest sinks related projects so that our forested wetlands results will be taken in the context of all forest related carbon cycle and sinks modeling results, particularly soils related sinks research. Our research is closely linked with a new GHG research project being undertaken at the Turkey Lakes Watershed *Roaming GHG-Hotspots (CO_2, CH_4, and N_2O): A Hydrologically Based Method for Mapping GHG Sources and Sinks in Forests.* This project is funded for three years and run collaboratively by University (I. Creed, U. Western Ontario – S. Schiff, U. Waterloo) and Federal Government (R. Bourbonniere & D. Jeffries, EC/NWRI – F. Beall & N. Foster, NRCan/CFS) researchers. Our initial PERD funded research provided a "seed" project from which the CFCAS proposal was drawn up. The continuation of our PERD funds for 2003-04 and 2004-05, as well as federal government in-kind support were instrumental in the proposal's success

The primary objective of the entire forest sinks program is to improve techniques for estimating the carbon budget of Canada's managed and unmanaged forest and forest wetland ecosystems and to identify trends and changes in carbon sequestration associated with forest management, land use change and climate variability and change.

Our research on forested wetlands addresses these specific sub-objectives:

- To understand the distribution and fate of soil carbon and the variable sink/source status of forested wetlands;
- by apportioning greenhouse gas fluxes among wetland and upland portions of catchments;
- by understanding hydrologic and biogeochemical processes that contribute to the spatial and temporal variability of greenhouse gas fluxes in forested catchments containing wetlands;
- To assess the impact of climate change and variability, disturbances and forest management practices on increasing carbon sequestration in Canada's forest wetland ecosystems;
- by develop datasets and conceptual models to incorporate this knowledge into distributed hydrological models and carbon budget models.

In addition to the policy implications for the department in assisting Canada to meet its Kyoto commitments, research into greenhouse gas exchange in forested catchments containing wetlands will provide new knowledge and understanding of:

- wetland ecosystems;
- soil biogeochemical processes;

- catchment hydrology;
- terrestrial - aquatic - atmospheric interactions;

with implications for and applications to departmental priorities in climate science and water resources science.

Methodology

During 2001-02, PERD contributed through the forested wetlands initiative to ongoing research conducted by partners at a forested wetlands site in southern Ontario (Beverly Swamp). Completed field-based studies begun by partners on the influence of climate and hydrology on GHG fluxes.

In subsequent years all forested wetland resources were utilized for Turkey Lakes Watershed work and new research was started at Beverly Swamp under the agricultural wetlands initiative. The research undertaken by the partners at the Turkey lakes Watershed began in April 2001 with the first increment of seed funding from PERD.

The study includes field survey, monitoring, process studies and modeling components. To date (2001-2004) the study has followed this course:

- Initiation: Site selection, initial surveys, installing equipment, gathering background data;
- Catchment Surveys: Soil surveys, digital elevation models (DEMs), initial greenhouse gas (GHG) measurements;
- Monitoring, Modelling and Process Studies: GHG measurements, implementation of terrain analysis model, preliminary process studies;
- Future Work: Increased partner participation and funding will result in more process studies, continued and expanded GHG measurements, incorporation into models of soil, dissolved and gaseous carbon fluxes from study catchments.

Goals, Outputs and Project Success Story

- Beverly Swamp: Field-based studies on the influence of climate and hydrology on greenhouse gas (CO_2 and CH_4), dissolved organic carbon and biogeochemical processes were completed;
- Turkey Lakes Watershed: Initiation (01-02): Initial survey work to select research sites; installing flux measurement infrastructure; gathering background data;

Catchment Surveys (02-03): Soil survey and soil organic carbon distribution; wetland boundary definition; digital elevation models (DEMs) on the selected catchments;

- initial greenhouse gas (GHG) measurements (CO_2 and CH_4) on representative transects; dissolved organic carbon export from the catchments;

- Monitoring, Modelling and Process Studies (03-04): Continuation of GHG measurements on the transects resulting in topographic distribution of CO_2 efflux; implementation of terrain analysis models on soil moisture distribution; preliminary process studies on CH_4 generation;

- Future Goals: More process studies on the generation of all three GHGs (CO_2, CH_4, N_2O), including preliminary stable isotope studies; continued and expanded GHG measurements to better delineate topographic, moisture and temperature control of GHG fluxes; incorporation of soil, dissolved and gaseous carbon fluxes from study catchments into models at the catchment scale; proposed linkages to more general forest carbon models, particularly soil carbon components.

The project will complete its first four years with a better understanding of the topographic, moisture and temperature controls on GHG fluxes from soils in tolerant northern hardwood forests characterized by complex terrains that include swamp components. The plan for the next five years will include expansion of this research to other forest types (*e.g.* boreal) and manipulation experiments to test the sensitivity of GHG generation processes to the impacts of climate alterations (*e.g.* drought). Results from these experiments will be combined with the early results to model sensitive processes and feed the knowledge upwards to larger scale forest models.

One of the project's highlights is the finding of topographic control of CO_2 efflux. Our transect studies of soil CO_2 efflux found that a transition zone exists at the footslopes which is characterized by the highest fluxes throughout the growing season, higher than both wetland and upland positions. This result is contrary to our initial hypothesis that upland positions would yield the highest fluxes. This result led us to more comprehensive studies of topographic controls of GHG fluxes in these complex catchments.

Funding

The average resources allocated for this project per fiscal year were $150,050 (2001-2002; 2002-2003). An average 86.4% of these resources came from PERD funds, the rest came from other sources (A-Base). The average leverage quotient of total resources to PERD resources for the project was 1.2.

Profiles by Strategic Intent

Climate Sector

Steps to Increase the Net GHG Uptake

Carbon Sequestration in a Boreal Deciduous Forest

Impact of Variability and Climate Change on Carbon Sequestration in a Boreal Deciduous Forest

Project Manager: Alan Barr

Project Objectives

This project, which focuses on the measurement of inter-annual climatic variability and its effect on carbon sequestration by three contrasting boreal forest ecosystems (aspen, black spruce and jack pine) evolved from an earlier project *The Impact of Climatic Variability and Change on Carbon Sequestration in a Boreal Deciduous Forest* which began in 1998 and was conducted at the aspen site only. This work is part of the Boreal Ecosystem Research and Monitoring Sites (BERMS) program, a joint initiative of the Climate Research Branch of MSC, the Canadian Forest Service, Parks Canada, and collaborating scientists from U.B.C. and Queen's U. The BERMS program began in 1997. The BERMS program is tightly integrated with modeling studies in POL 6.2.1. BERMS recently became the flagship flux station of the Fluxnet-Canada Research Network, a new national network that is studying the influence of climate and disturbance on carbon cycling in forest and peatland ecosystems. BERMS is also linked to international flux-tower networks, including Ameriflux, CarboEurope and AsiaFlux, through the global FLUXNET program.

The objective of this project is:

- To measure and analyze the effect of inter-annual climate variability on the carbon and water balances of deciduous, wet coniferous and dry coniferous boreal forest ecosystems, and create an integrated, stand-level database, including carbon, water and energy fluxes, soil CO_2 efflux, climate, soil moisture and biophysical data and metadata, for validating process models of the forest carbon balance.

This project is closely coupled to the development and validation of Canadian Land Surface Scheme (CLASS) of MSC, the land-surface scheme used in Canadian climate models. The BERMS data are essential for model development and validation. Current efforts (2002-2005) are focused on the implementation of a carbon cycle module in CLASS and the assessment of the model's ability to simulate the influence of seasonal and inter-annual climate variability on the carbon balance of the boreal forest at the stand level. The goal is an improved representation of land surface processes for boreal forest, with a fully coupled carbon cycle model, in the Canadian GCM and RCM.

Methodology

The exchanges of carbon, weather and energy between the forest and the atmosphere are measured using the tower-based eddy-covariance technique. A demonstrated strength of the BERMS program is the use of standardized instrumentation and data-processing protocols at all sites. The high degree of measurement standardization enables a credible cross-site analysis of inter-ecosystem differences in carbon sequestration and its climatic controls. Another strength of the BERMS program is the development of an exemplary Data Information System, which has been recently adopted for use by the Fluxnet-Canada Research Network.

Goals, Outputs and Project Success Story

This project's most significant output to date is the integrated, stand-level database, available on a password protected website. Analysis of the data is producing new insights into the key biophysical and climatic processes that control the balances of carbon, water and energy in boreal forest. The database is also being used by collaborating modeling groups, including the modeling theme in this POL, to improve the formulation of key processes in ecosystem carbon cycle models.

The BERMS data are being used to strengthen our understanding of the key climatic and biophysical processes that control the forest's carbon and water cycles, including climate warming and drought. The aspen site has large inter-annual differences in carbon sequestration that are controlled primarily by spring temperature; warm springs promote early leaf out and increase photosynthetic carbon uptake. A secondary control on carbon sequestration is the leaf area index, with diminished leaf area index and carbon uptake in years following drought. In contrast to the aspen ecosystem, the black spruce and jack pine ecosystems sequester less carbon and are less sensitive to inter-annual climatic variability.

The BERMS data are being used by many collaborating groups to validate and improve national land surface process and ecosystem carbon budget models, including C-CLASS, IBIS, BEPS-INTEC, and ECOSYS.

Funding

The average resources allocated for this project per fiscal year were $436,900 (2001-2002; 2002-2003). An average 15.8% of these resources came from PERD funds, the rest came from other sources (A-Base, others such as CCAF, NSERC). The average leverage quotient of total resources to PERD resources for the project was 6.4.

Profiles by Strategic Intent

Climate Sector

Steps to Increase the Net GHG Uptake

Wetlands in Agricultural Context-Carbon Sink Potential

Wetlands in the Agricultural Context-Carbon Sink Potential

Project Manager: Rick Bourbonnière

Project Objectives

The wetlands related sinks research began under the "new" PERD structure. Our work is linked within the POL 6.2.1 structure to all of the other agricultural sinks related projects so that our agricultural wetlands results will be taken in the context of all agriculture related carbon cycle and sinks modeling results, particularly soils related sinks research. Our PERD funded research provided seed money for the first wetland focused study to be undertaken under the auspices of the Prairie Carbon Research Group, whose members include Federal, Provincial, University and NGO organizations. Ducks Unlimited Canada (DUC) provided funding and in-kind resources for several related wetland studies including those that are most closely allied with our PERD studies. University partners provided in-kind laboratory and field support from staff and students. Recently (Fall 2003), a new NSERC-BIOCAP strategic project grant was funded to focus on GHG sources and sinks in upland/riparian/wetland transects at experimental sites in Saskatchewan and Manitoba. Closely associated with this project is the DUC and PERD funded Riparian/Open Water studies that are a continuation of our original work. These are ongoing at three open water sites, one each in Manitoba, Saskatchewan and Alberta.

In the context of the entire POL6.2.1 agriculture component the overall goals are to improve methodology, understand processes, evaluate management practices and improve and update models of greenhouse gas fluxes from agroecosystems in order to quantify carbon sequestration and provide a verifiable carbon credit accounting system.

Our research of wetlands in the agricultural landscape addresses the following sub-objectives:

- To understand the source/sink status of wetlands and riparian zones in agricultural landscapes in relation to uplands (crop and range lands);
- by measuring greenhouse gas fluxes along transects in several regions of Canada;
- by carrying out process studies to determine the impact of upland management practices (*e.g.* nutrient management) on riparian zone and wetland carbon budget;
- by building and testing a wetland carbon process model.
- To assess the impact of climate change, farming practices and land use change on the ability of agricultural wetlands to sequester carbon;
- By providing data sets from representative sites and interpretation to allow scaling up to landscape level.

In addition to the policy implications for the department in assisting Canada to meet its Kyoto commitments, research into greenhouse gas exchange in agricultural landscapes containing wetlands will provide new knowledge and understanding of:

- wetland ecosystem vulnerability;
- soil biogeochemical processes;
- hydrology at a landscape scale;
- terrestrial - aquatic - atmospheric interactions;

with implications for and applications to departmental priorities in climate science, waterfowl habitat and water resources science.

Methodology

During 2001-02, PERD resources for agricultural wetlands and forested wetlands were combined and supported ongoing research conducted by partners at a forested wetlands site in southern Ontario (Beverly Swamp). Completed field-based studies begun by partners on the influence of climate and hydrology on GHG fluxes. Initial scoping meetings with the Prairie Carbon Research Group were held to plan research along upland-riparian-wetland transects with the initial studies to begin in 2002-03 with PERD seed funding.

In subsequent years all agricultural wetland resources were utilized for new research started at Beverly Swamp and at a prairie wetland site (St. Denis, SK). The new research undertaken by the partnerships began at Beverly Swamp in the fall of 2001 and at St. Denis April, 2002. As partner funding and PERD funding increased annually the activities ramped up in proportion, including the addition of new sites in Manitoba and Alberta.

The study includes field survey, monitoring, process studies and modeling components. To date (2001-2004) the study has followed this course:

- Initiation: Site selection, initial surveys, installing equipment, gathering background data;
- Initial Surveys: Soil surveys, initial greenhouse gas (GHG) measurements;
- Monitoring, Modelling and Process Studies: GHG measurements, digital elevation models (DEMs), preliminary process studies;
- Future Work: Increased partner participation and funding will result in more process studies, continued and expanded GHG measurements, incorporation into models of soil, dissolved and gaseous carbon and nitrogen fluxes from wetlands and associated uplands and riparian zones.

Goals, Outputs and Project Success Story

- Beverly Swamp, ON
- Initiation (Fall 2001): Transect selection for riparian zone and cropland (local farmer), installation of collars;

- Initial Surveys (2002-03): GHG fluxes (CO_2 and CH_4) at cropland-riparian transects and wetland reference site;
- Monitoring, Modelling and Process Studies (2003-04): Install met station, install hydrologic network, digital elevation model, nitrate reduction experiments, full growing season CO_2 and CH_4 flux measurements, water quality groundwater and stream;
- Future Work (2004-05): Increased frequency of measurement, additional transects, laboratory and field process experiments, conceptual model
- St. Denis, SK
- Initiation (2002-03): Transect selection at Pond 1 – installation of riparian transect, initial trials with chamber design - pond dried quickly;
- Initial Surveys (2003-04): Installation of secure riparian/open water transect, construction of floating chamber systems, construction of continuous CO_2 flux monitor, some summer flux measurements;
- Monitoring and Process Studies (2004-05): With increased partner funding will measure GHG fluxes on the transect including the open water for the entire growing season, water chemistry and light regime monitoring as well.
- Pond Transects – Manitoba and Alberta Sites
- Initiation (2003-04): Partner funded effort on riparian / open water transect, initial flux results;
- Initial Surveys (2004-05): With increased partner and PERD funding, the research at this site should be at, or near the frequency and type as St. Denis;
- Modelling: We will work together with our modelling partner to update the existing model with new information;
- Related Work: Since 2002-03 a survey of restored wetlands (DUC) in the three prairie provinces for GHG flux was underway with the aim of cataloguing changes with time since initiation of restoration.

Most of the work is still in its early stages, but the major success story is the high degree of partnership and leverage that has evolved since the PERD seed study began in 2001-02. Many related studies are underway and together the Prairie Carbon Research Group will begin understand GHG fluxes in a landscape context. The contribution of wetlands to the sink/source status of the agricultural landscape will be clear and included in the wetland carbon model.

Funding

The average resources allocated for this project per fiscal year were $102,000 (2001-2002; 2002-2003). An average 28.4% of these resources came from PERD funds, the rest came from other sources (A-Base, B-Base, industry (DUC) and others such as McMaster U., U. of Saskatchewan, U. Tor. Miss.). The average leverage quotient of total resources to PERD resources for the project was 3.5.

Advice/Coordination/Assessment

Project Manager: Henry Hengeveld

Project Objectives

This project is a continuation of a PERD project initiated in 1981/82. While the project has included the role of POL leader, the services provided go well beyond the sinks issue identified as the theme for POL 6.2.1.

The objective of this project is to ensure effective delivery of POL outputs and a mechanism for advising policy makers of scientific research results as needed for national and international negotiations and policy development with respect to greenhouse gas fluxes and climate change.

Much of the climate change science assessment and communication activities undertaken within this project are of generic interest to all government climate change policy advisors/makers, particularly within EC. It is also an important part of EC outreach activities to the public.

Methodology

The science advisor activities undertaken within this project include:

- assessment of the national and international science with respect to greenhouse gas sources and sinks and their significance with respect to the broader issue of climate change;
- provision of advice to research program managers and scientists on priority research areas to ensure such activities are policy relevant, and organizing related science workshops;
- provision of advice to the policy community with respect to the current status of science relevant to greenhouse gas sinks, climate change and other related issues;
- preparation of related papers, reports and briefing notes;
- and presentation of seminars as appropriate.

The science advisor will also serve as leader for the EGGS POL. Related responsibilities include the organization of technical meetings to assist the POL committee in its further development and evaluation of the POL activity plans.

Goals, Outputs and Project Success Story

Outputs for 2002-03 included:

- A review of some 400 climate change research papers appearing in international peer reviewed literature in 2001 was completed. The review will be released as the spring 2003 issue of the newsletter CO_2/Climate Report;

- Weekly reports on new science highlights appearing in the peer-reviewed literature were prepared and circulated electronically to selected senior government policy makers and managers. In addition, more technical monthly reports of literature highlights were circulated to an extensive list of scientists and other interested readers;

- In collaboration with the POL steering committee, organized and hosted a,mid-cycle POL workshop to assess progress in meeting POL deliverables and identify priorities for Cycle 2 POL activities and outputs. Some 60 research scientists and managers from the four natural resources departments and several academic institutions participated. A report of the workshop is in preparation and will be released in CD-ROM format;

- During the year, three articles and reports on climate change science were completed and published in journals or reports (see Appendix A), and 18 oral presentations on the science of climate change were made at meetings, workshops, conferences and public gatherings;

- As lead on POL 6.2, the science advisor coordinated the reporting on activities undertaken under the POL 6.2 plan.

Recent highlights of this project include the 1993 POL workshop and very satisfactory external evaluation of POL, indicating that deliverables are all on target and that related PERD investment has achieved high returns.

Funding

The average resources allocated for this project per fiscal year were $248,000 (2001-2002; 2002-2003). An average 43.6% of these resources came from PERD funds, the rest came from other sources (A-Base). The average leverage quotient of total resources to PERD resources for the project was 2.3.

Annex 1

POL Objective Leaders

ANNEX 1 POL OBJECTIVE LEADERS FROM ALL PARTICIPATING DEPARTMENTS

POL Number	POL Title	POL Leader	E-Mail Address
1.2.1	Offshore Environmental Factors (OEF)	Peter Smith	smithpc@mar.dfo-mpo.gc.ca
1.2.2	Northern Hydrocarbon Production	Benoit Beauchamp	bbeaucha@nrcan.gc.ca
1.2.3	Marine Transportation and Safety (MTS)	Robert Frederking	robert.frederking@nrc-cnrc.gc.ca
1.3.1	Flaring Research Initiative (FRI)	Bill Reynen	bill.reynen@ec.gc.ca
1.3.3	Soil and Groundwater Remediation	Saviz Mortazavi	Saviz.mortazavi@ec.gc.ca
2.1.1	Support the Development of Technological and Other Measures to Control and Reduce Emissions of Particulate Matter (Air Quality-Particles research)	Keith Puckett	keith.puckett@ec.gc.ca
2.1.2	Advanced Fuels and Transportation Emissions Reduction (AFTER)	Greg Smallwood	Greg.Smallwood@nrc.ca
2.2.2	Fuel Cells, Electric and Hybrid Vehicles	Martin Hammerli	hammerli@nrcan.gc.ca
2.2.4	Optimisation of the Energy Efficiency of Transportation Systems	Michael Ball	ballma@tc.gc.ca
3.2.4	Energy Management for Sustainable Communities	Chris Snoek	csnoek@nrcan.gc.ca
4.3.3	Research, Development, and Deployment for Industrial Separation and Refrigeration (SEPREF)	Jean Paquette	Jean.paquett@nrcan.gc.ca
5.1.1	Electricity from Renewable Energy Technologies	Claude Faucher	cfaucher@nrcan.gc.ca
5.2.1	Characterization of Canadian Fuels and their Emissions (COFE)	Dave Hughes	dhughes@nrcan.gc.ca
5.2.2	Clean and Efficient Combustion Technologies for Large Utility Electricity Generation	Michael Burke	Michael.burke@nrcan.gc.ca
5.2.3	CO_2 Capture and Storage	Kelly Thambimuthu	Kelly.thambimuthu@nrcan.gc.ca
6.1.1	Climate Change Impacts on the Energy Sector (CCIES)	Allyn Clarke	clarkea@mar.dfo-mpo.gc.ca
6.2.1	Enhancement of Greenhouse Gas Sinks (EGGS)	Henry Hengeveld	henry.hengeveld@ec.gc.ca

Annex 2

Publications

Annex 2
Publications
Objective 1.2.1
Offshore Wind and Wave Design Criteria

ANNEX 2 : RECENT PRESENTATIONS, CONFERENCES AND PUBLICATIONS

Strategic Intent 1 : Strategic Direction 2 : Objective 1.2.1

Offshore Environmental Factors (OEF)

Project: Offshore Wind and Wave Design Criteria

Publications:

Caires, S., A. Sterl, J.-R.Bidlot, N. Graham and V. Swail, 2004. Intercomparison of different wind wave reanalyses. J. Climate, in press.

Lozano, I., and V.R. Swail, 2002. The link between wave height variability in the North Atlantic and the storm track activity in the last four decades. Atmosphere-Ocean 40(4): 377-388.

Moat, B.I., 2003. Quantifying the effects of airflow distortion on anemometer wind speed measurements from merchant ships. Ph.D. Thesis. University of Southampton, UK, 163 p.

Wang, X.L., and V.R. Swail, 2002. Trends of Atlantic wave extremes as simulated in a 40-year wave hindcast using kinematically reanalyzed wind fields. J. Climate, 15, 1020-1035.

Wang, X.L., and V.R. Swail, 2004. Historical and possible future changes of wave heights in northern hemisphere oceans. Atmosphere-Ocean Interactions – Volume II, Wessex Institute of Technology in conjunction with Computational Fluid Mechanics, in press.

Wang, X.L., F.W. Zwiers and V.R. Swail, 2004. North Atlantic Ocean wave climate change scenarios for the 21st century. Accepted in J. Climate.

Yelland, M. J., B. I. Moat, R. W. Pascal and D. I. Berry , 2002: CFD model estimates of the airflow over research ships and the impact on momentum flux measurements. Journal of Atmospheric and Oceanic Technology Vol. 19, No. 10, pp. 1477–1499.

Conference Papers and Presentations:

Berek, G., 2002. Effects of Sampling Rate on Extreme Value Analysis of Wave Height. Proceedings 7th International Workshop on Wave Hindcasting and Forecasting, 21-25 October 2002, Banff, Alberta.

Caires, S. and A. Sterl, 2003. The ERA-40 wind and wave data. Proceedings of CLIMAR-II: Workshop on Advances in Marine Climatology, Brussels, Belgium, 17-22 November 2003. JCOMM Technical Report.

Caires, S., A. Sterl, J.-R.Bidlot, N. Graham and V. Swail, 2002. Climatological Assessment of Reanalysis Ocean Data. Proceedings 7th International Workshop on Wave Hindcasting and Forecasting, 21-25 October 2002, Banff, Alberta.

Cardone, Vincent J., 2003. Reduction of uncertainty of marine wind fields for ocean response modeling by utilizing the QuikSCAT dataset. Proceedings of CLIMAR-II: Workshop on Advances in Marine Climatology, Brussels, Belgium, 17-22 November 2003. JCOMM Technical Report.

Cox, Andrew T., Brian T. Callahan, Vincent J. Cardone and Val R. Swail, 2002. Case Studies of Tropical to Extra-Tropical Cyclone Conversion in the Western North Atlantic: Wind Field Kinematics and Wave Response. Proceedings 7th International Workshop on Wave Hindcasting and Forecasting, 21-25 October 2002, Banff, Alberta.

Environment Canada, 2002. Proceedings 7th International Workshop on Wave Hindcasting and Forecasting, 21-25 October 2002, Banff, Alberta, 534 pp.

Annex 2

Publications

Objective 1.2.1

Offshore Wind and Wave Design Criteria

Hogg, W.D., and V. R. Swail, 2002. Effects of Distributions and Fitting Techniques on Extreme Value Analysis of Modelled Wave Heights. Proceedings 7th International Workshop on Wave Hindcasting and Forecasting, 21-25 October 2002, Banff, Alberta.

Moat, B.I., 2003. Quantifying the effects of airflow distortion on wind speed measurements from Voluntary Observing Ships. Proceedings of CLIMAR-II: Workshop on Advances in Marine Climatology, Brussels, Belgium, 17-22 November 2003. JCOMM Technical Report.

Orelup, E.A., A. Niitsoo and V. J. Cardone, 2002. North Atlantic Wave Climate Extremes and their Variability. Proceedings 7th International Workshop on Wave Hindcasting and Forecasting, 21-25 October 2002, Banff, Alberta.

Swail, V.R., 2003. A 50-year wind and wave hindcast for the east coast of Canada. International Oil and Gas Producers (OGP) Metocean Committee, San Francisco, CA, 21 October 2003.

Swail, V.R., Xiaolan L. Wang and Andrew Cox, 2002. The Wave Climate of the North Atlantic - Past, Present and Future; . Proceedings 7th International Workshop on Wave Hindcasting and Forecasting, 21-25 October 2002, Banff, Alberta.

Taylor, Peter K., 2003. Improved meteorological measurements from merchant ships. Proceedings of CLIMAR-II: Workshop on Advances in Marine Climatology, Brussels, Belgium, 17-22 November 2003. JCOMM Technical Report.

Thomas, B., and V. Swail, 2002. Methods to Reduce Biases Between Wind Speeds from Ships and Buoys. Proceedings 7th International Workshop on Wave Hindcasting and Forecasting, 21-25 October 2002, Banff, Alberta.

Thomas, B.R., and V.R. Swail, 2003. Effect of vessel type and platform relative wind direction on the comparison between buoy and ship wind speeds. Proceedings of CLIMAR-II: Workshop on Advances in Marine Climatology, Brussels, Belgium, 17-22 November 2003. JCOMM Technical Report.

Thomas, B.R., and V.R. Swail, 2003. Methods to homogenize wind speeds from ships and buoys. Proceedings of CLIMAR-II: Workshop on Advances in Marine Climatology, Brussels, Belgium, 17-22 November 2003. JCOMM Technical Report.

Coupled Atmosphere-Ocean Wave Models

Project: Data Assimilation into Coupled Atmosphere-Ocean Wave Models

Presentations and Conferences

Lalbeharry, Roop, 2003: Description of the CMC ocean wave model and verification system. Lecture presented at the WMO Workshop on Wind Wave and Storm Surge Analysis and Forecasting for Caribbean Countries, Dartmouth, Nova Scotia, 16-20 June 2003.

Lalbeharry, Roop, 2002: Comparison of the performances of three state-of-the-art ocean wave models in extreme storm case. Preprint, 7th International Workshop on Wave Hindcasting and Forecasting, 21-25 October 2002, Banff, Alberta, published by Meteorological Service of Canada.

Lalbeharry, Roop, 2002: "Wave height simulations using WAM, WW3 and SWAN for selected storm cases" presented at the 9th WISE Meeting, 12-16 May 2002, Bergen, Norway.

Lalbeharry, Roop, 2002: "Comparison of the performances of three state-of-theart ocean wave models in extreme storm case" Preprints, 7th International Workshop on Wave Hindcasting and Forecasting, 21-25 October 2002, Banff, Alberta.

Lalbeharry, R. and C. Farrell, 2003: Improving operational wave forecasts using a high resolution wave model during a two-month period: December 2002 - January 2003 Presentation at WISE Meeting 4-8 May 2003, Florianopolis, Brazil.

Annex 2

Publications

Objective 1.2.1

Coupled Atmosphere-Ocean Wave Models

Publications

Bidlot, Jean-Ramond, Damian J. Holmes, Paul A. Wittmann, Roop Lalbeharry, and Hsuan S. Chen, 2002: Intercomparison of the performance of operational ocean wave forecasting systems with buoy data. Weather and Forecasting, 19, 287-310. (Refereed journal paper).

Buehner, M, 2002: Assimilation of ERS-2 scatterometer winds using the Canadian 3D-Var, Atmosphere-Ocean 40, 361-376. (Refereed journal paper).

Lalbeharry, Roop, 2002: Evaluation of the CMC regional wave forecasting system against buoy data: Atmosphere-Ocean, 40(1), 1-20 (refereed journal paper).

Operational Ice Modelling

Project : Operational Ice Modelling

Presentations

A. Barker, M. Sayed and T. Carrieres: Empirical Determination of Iceberg Draft and Cross-Sectional Areas. To be submitted as a conference paper to International Society of Offshore and Polar Engineering 2004

M. Sayed, T. Carrieres, and S. Savage. Testing Of A Two-Category Ice Thickness Redistribution Model. Conference paper for International Society of Offshore and Polar Engineering 2003

S. Savage: Summary Report on CIS Sea-Ice Workshop. Sept 2003.

Detection of Icebergs from Space-Borne SAR

Project: Operational Detection of Icebergs from Space-Borne SAR

Presentations and Report

C-CORE, "IDS Software Documentation", Contract Report Number R-02-035-193 for Canadian Ice Service, February 2003.

C-CORE, "Presentation to CIS Operations on RADARSAT-1 for Iceberg Detection", C-CORE Contract P-03-037 deliverable, October 2003.

C-CORE, "The capabilities for iceberg detection using RADARSAT-1", C-CORE Contract P-03-037 report for the Canadian Ice Service, January, 2004.

Strategic Intent 1: Strategic Direction 2: Objective 1.2.2

Objective 1.2.2

Northern Hydrocarbon Production

Environmental Risk from Petroleum Exploration

Project: Minimizing Environmental Risk from Petroleum Exploration in the Lower Mackenzie River Valley of the Northwest Territories

There is not a published final report. We anticipate the completion of a comprehensive report on Phase I and II of the project to be distributed this spring.

Presentations

Johnston, L., 2002, Development of Constraints Mapping to Minimize the Environmental Risk of Industrial Activities in the Mackenzie Delta- A Feasibility Assessment, presented to government and industry in 2002 for the promotion of the project.

Annex 2

Publications

Objective 1.2.3

Small Glacial Mass Distributions

Strategic Intent 1: Strategic Direction 2: Objective 1.2.3

Marine Transportation and Safety

Project: Prediction of Small Glacial Mass Distributions

Contractor Reports

Savage, S.B. Feb 2004: Equations for CIS Bergy Bit Modelling.

Crocker, G. Feb 2004: Analysis Of Iceberg Model Verification Data Collected To June 2003.

Crocker, G. Jul 2003: Collection of Iceberg Model Verification Data – June 2003.

Objective 1.3.1

Strategic Intent 1: Strategic Direction 3: Objective 1.3.1

Flaring Research Initiative

Publications

Johnson, M.R., Spangelo, J.L., and Kostiuk, L.W., A Characterization of Solution Gas Flaring in Alberta, Journal of the Air and Waste Management Association, in press.

Johnson, M.R., Wilson, D.J., and Kostiuk, L.W., A Fuel Stripping Mechanism for Low-momentum Jet Diffusion Flames in a Crossflow, Combustion Science and Technology, in press.

Johnson, M.R. and Kostiuk, L.W. (2002) Visualization of the Fuel Stripping Mechanism for Wake-Stabilized Diffusion Flames in a Crossflow Turbulent Mixing and Combustion, International Union of Theoretical and Applied Mechanics, Kluwer Academic Publishers.

Web Site URL

http://www.mece.ualberta.ca/groups/combustion/flare/

Technical Reports

Johnson, M.R., "Wake-Stabilized Diffusion Flames in Crossflow: Application to the Efficiencies of Gas Flares", Ph.D. Thesis, Department of Mechanical Engineering, University of Alberta, July 3, 2001, 171 pages.

Bachu, S., Adams, J., Buschkuehle, B. and Michael, K. "Compilation of Subsurface Data for Acid Gas Disposal Sites in Alberta", Alberta Geological Survey, March 2002.

Shewchuk, S. and Spellicy, R.L., "Well Test Plume Monitoring", Saskatchewan Research Council, February 2002.

Chambers, A., "Well Test Plume Monitoring - Literature Review", Alberta Research Council, December 2001

Objective 1.3.3

Strategic Intent 1: Strategic Direction 3: Objective 1.3.3

Soil and Ground Remediation

Natural Wetlands vs. Toxic Organics

Project: Natural Wetlands- Containment, Transformation and Remediation of Toxic Organics from Natural Gas Condensates and Process Chemicals

Publications and Presentations

Doucette, W.J. , J.K. Chard, B. Moore, W. Staudt, and J.V. Headley. 2003. Determination of sulfolane and DIPA by hydroponically grown cattails. CAPP platform presentation, Calgary, Alberta.

Annex 2

Publications

Objective 1.3.3

Natural Wetlands vs. Toxic Organics

Doucette, W.J. , J.K. Chard, B. Moore, W. Staudt, and J.V. Headley. 2003. Determination of sulfolane and DIPA by hydroponically grown cattails, SETAC Platform presentation, Austin, Texas, USA.

Headley, J.V. and K.M. Peru. 2004. Petroleum and Wetlands. Invited review. ENCYCLOPEDIA OF WATER SCIENCE. 10 pp (in press).

Peru K. M., J.V., Headley, and and W. J. Doucette. 2003. LC/MS/MS selected reaction monitoring of DIPA in cattails Typha latifolia. (in review, Rapid Communications in mass spectrometry).

Peru, K. M.; J V. Headley and W. J. Doucette. 2003. Determination of Natural Gas Processing Chemical Uptake in Cattails (Typha latifolia) Utilizing Multiple Reaction Monitoring ESI/MS with Ion Exchange Chromatography. presented at the 51st American Society for Mass Spectrometry, Montreal, June 8-12, 2003.

Rockwell, L, J.V.Headley, and J. Germida 2003. Plant uptake of petroleum hydrocarbons in natural wetlands. Phytoremediation Workshop, Saskatoon, June 19,20, 2003.

Project: Remediation of Naphthenic Acids in Subsurface Soils and Groundwater at Oil Extraction Plants

Naphthenic Acids in Subsurface Soils and Groundwater

Publications

Headley, J.V. and McMartin, D. 2004. A review of fate and transport of naphthenic acids in aquatic environments. Environmental Sci and Health Part A. (in press)

Headley, J.V., K.M. Peru, D. McMartin and M. Winkler. 2002. Determination of dissolved naphthenic acids in natural waters by using negative-ion electrospray mass spectrometry. Jour of AOAC Int. 85(1):182-187.

Headley, J.V., S. Tanapat, G. Putz and K.M. Peru. 2002. Biodegradation Kinetics of Geometric Isomers of Model Naphthenic Acids in Athabasca River Water. Canadian Water Resources Journal 27(1):25-42.

McMartin, D., J.V. Headley, J. Gillies, D.Friessen and K.M. Peru. 2004. Photodegradation of naphthenic acid mixtures in natural waters. J Environmental Sci. and Health. Part A.(in press).

McMartin, D.W., J.V. Headley, D.A. Friesen, K.M. Peru and J.A. Gillies. Photolysis of naphthenic acids in natural waters. 38th Annual Central Canadian Symposium on Water Quality Research. February 10-11, 2003. Canada Centre for Inland Waters (CCIW), Burlington, Ontario, Canada.

Peng, J., J.V. Headley and S.L. Barbour. 2002. Adsorption of single-ring model naphthenic acids on soils. Canadian Geotechnical Journal 39: 1-8.

Project: The Role of Sulfate Reduction in the Bioremediation Technologies for Hydrocarbon Contamination in Groundwater

Sulfate Reduction in Bioremediation Technologies

Publications

Van Stempvoort, D., Maathuis, H., Jaworski, E., Mayer, B. and Rich, K. 2004. Oxidation of methane in cold, anaerobic ground Water, linked to bacterial sulfate reduction. Submitted to Ground Water

Van Stempvoort, D.R., Armstrong, J. and Mayer, B. 2002. Bacterial sulfate reduction in biodegradation of hydrocarbons in low-temperature, high-sulfate groundwater, western Canada. Proceedings, 2002 Petroleum Hydrocarbons and Organic Chemicals in Ground Water: Prevention, Detection, and Remediation, 19th Annual Conference and Exposition (NGWA/API), November 6-8, 2002, Atlanta, Georgia, pp. 244-259.

Van Stempvoort, D.R., Armstrong, J. and Biggar, K. 2002. Significance of microbial sulfate reduction in biodegradation of hydrocarbons in groundwater. Proceedings, 55th Canadian Geotechnical and 3rd Joint IAH-CNC /CGS Conference, "Ground and Water: Theory to Practice," October 21-23, 2002, Niagara Falls, Ontario, pp. 885-892.

Project: Remediation of Hydrocarbon-Contaminated Sites by Monitored Natural Attenuation (MNA)

Reports

"CORONA NSERC CRD Annual Report to April 1, 2003". Report to Natural Sciences and Engineering Research Council (NSERC).

"Natural attenuation of petroleum hydrocarbons at upstream oil and gas facilities". Report to: Coordination of University Research for Synergy and Effectiveness (COURSE), Research Project No. 1294. Report #1 Reporting period to June 1, 2002.

"Evaluation of uncertainty associated with common groundwater sampling protocol to support monitored natural attenuation". Report to Alberta Environment, KI-C50030104, April 2002.

"Evaluation of site characterization and groundwater sampling methods to support monitored natural attenuation". Report to Alberta Environment, KI-C50030104, March 2002.

"Assessment of monitored natural attenuation at Alberta oil and gas facilities", Report to: Canadian Association of Petroleum Producers (CAPP), Alberta Environment and Environment Canada, March 2002, Pub # 2002-0010.

Conferences

T. Epp, J.E. Armstrong and K.W. Biggar, 2002. Guideline Development for Use of Monitored Natural Attenuation at Contaminated Sites in Alberta. Proceedings of: European Conference on Natural Attenuation, October 15-17, 2002, Heidelberg, Germany, pp. 64-67.

T. Epp, J.E. Armstrong and K.W. Biggar, 2002. Guideline Development for Use of Monitored Natural Attenuation at Contaminated Sites in Alberta. Proceedings of: Remediation Technologies Symposium (RemTech) 2002 (ESAA), October 16-18, 2002 Banff Alberta

D.R. Van Stempvoort, J.E. Armstrong, and B. Mayer, 2002. Bacterial Sulfate Reduction in Biodegradation of Hydrocarbons in Low-Temperature, High-Sulfate Groundwater, Western Canada, Proceedings of 2002 Petroleum Hydrocarbons and Organic Chemicals in Ground Water: Prevention, Detection, and Remediation, 19th Annual Conference and Exposition (NGWA/API), November 6-8, 2002, Atlanta, Georgia, pp. 244-259.

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J.E.Armstrong, K.W. Biggar, W.J. Staudt, B.J. Moore and K.M. Cross. 2002. Monitored Natural Attenuation at Upstream Oil and Gas Sites in Alberta. *Western Environment Business*, Vol. 3, Issue 2: 16-18

Technology Transfer

"Monitored natural attenuation at upstream oil and gas sites", Presentation at 2002 Environmental Research and Technology Development (R&D) Forum for the Upstream Oil & Gas Industry. Petroleum Technology Alliance Canada, Calgary, January 31, 2002.

"Monitored natural attenuation: a new approach to site remediation" Presentation at 7th Annual Enviro-Test Laboratories Calgary Seminar, January 29, 2002.

"Monitored natural attenuation and management of contaminated groundwater" Presentation at Contaminated Site Solutions Conference January 17-18, 2002.

Project: Biological Barriers in Fractured Bedrock

Peer reviewed articles

Castegnier, F., Ross, N. Chapuis, R. P., Deschênes, L., and Samson, R. 2004. Stability of a Nutrient-Starved Biofilm in a Limestone Fracture, Water Research, Submitted.

Ross, N., Novakowski, K., Lesage, S., Deschênes, L., and Samson, R. 2003. Development and Resistance of a Biofilm in a Planar Fracture, Journal of Environmental Quality, Submitted.

Novakowski, K. S., Bickerton, G. S., Lapcevic, P. A., Voralek, J. W., and Ross, N. 2003. Measurements of groundwater velocity in discrete fractures, Water Resources Research, Submitted.

Ross, N. and Bickerton, G. 2002. Application of Biobarriers for Groundwater Containment at Fractured Bedrock Sites, Remediation, Vol. 12, No. 3, pp. 5-21.

Conference Proceedings

Ross, N., Bickerton, G., Voralek, J., Lesage S., Novakowski, K., Deschênes, L., and Samson, R. 2003. A Field demonstration of the development of a biological barrier in a fractured shale, In Situ and On-Site Bioremediation – The Seventh International Symposium, June 2-5, Orlando, Florida.

Ross, N., Novakowski, K., Lapcevic, P., Voralek, J., Brown, S., Kennedy, C., Yazicioglu, B. M., Samson, R., and Lesage. S. 2002. Biofilm Development in a Large-scale Planar Fracture, Remediation of Chlorinated and Recalcitrant Compounds – The Third International Conference, May 20-23, Monterey, California.

Ross, N., Lapcevic, P., Lesage, S., Novakowski, K., Deschênes, L., and Samson, R. 2001. Biobarriers in Fractured Rock: Concept Development and Experimental Design, Fractured Rock 2001, March 26-28, Toronto, Canada.

Presentations:

Bickerton, G., Ross, N., and Voralek, J. 2004. Characterizing biofilm development in fractured bedrock using hydraulic testing and point dilution, 39th Central Canadian Symposium on Water Pollution Research, February 10-11. Burlington, Ontario, Accepted.

Charbonneau, A. M., Novakowski, K. S., and Ross, N. 2004. The Effect of Biofilm Development on Solute Diffusion in Low Permeability Rock, 39th Central Canadian Symposium on Water Pollution Research, February 10-11. Burlington, Ontario, Accepted.

Ross, N., Bickerton, G., Voralek, J., Lesage S., Novakowski, K., Deschênes, L., and Samson, R. 2003. A Field demonstration of the development of a biological barrier in a fractured shale, In Situ and On-Site Bioremediation – The Seventh International Symposium, June 2-5, Orlando, Florida.

Ross, N., Bickerton, G., Voralek, J., Lesage S., Novakowski, K., Deschênes, L., and Samson, R. 2003. A Field demonstration of the development of a biological barrier in a fractured shale, Americana 2003, March 19-21, Montreal, Quebec.

Ross, N., Novakowski, K., Voralek, J., Kennedy, C., Samson, R., and Lesage, S. 2002. Invited Speaker: Biofilm Development in a Large-Scale Planar Fracture, University Consortium Solvents-in-Groundwater Research Program Annual Meeting, June 4-6, Orangeville, Ontario.

Ross, N., Novakowski, K., Lapcevic, P., Voralek, J., Brown, S., Kennedy, C., Yazicioglu, B. M., Samson, R., and Lesage. S. 2002. Biofilm Development in a Large-scale Planar Fracture, Remediation of Chlorinated and Recalcitrant Compounds – The Third International Conference, May 20-23, Monterey, California.

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Annex 2

Publications

Objective 1.3.3

Biological Barriers in Fractured Bedrock

Poster Presentations:

Castegnier, F., Ross, N., Chapuis, R. P., Deschênes, L., and Samson, R. 2004. Stability of a Nutrient-Starved Biofilm in a Limestone Fracture, 39th Central Canadian Symposium on Water Pollution Research, February 10-11. Burlington, Ontario, Accepted.

Ross, N., Filion, D., Brown, S., Millar, K, and Lesage, S., and Deschênes, L. 2001. Stimulation of Groundwater Bacteria to Develop a Biobarrier: Ecotoxicological Responses, Changing Environmental Awareness: Societal Concerns and Scientific Responses – SETAC 22nd Annual Meeting in North America, 11-15 November, Baltimore, Maryland.

Ross, N., Lapcevic, P., Lesage, S., Novakowski, K., Deschênes, L., and Samson, R. 2001. Biobarriers in Fractured Rock: Concept Development and Experimental Design, Fractured Rock 2001, March 26-28, Toronto, Canada.

Solar Detoxification of Groundwater

Project: Solar Detoxification of Groundwater

Presentations

"Solar Detoxification – Treatment of Contaminated Groundwater", ESAA Remediation Technology Symposium, October 2002.

"Solar Detoxification – Treatment of Contaminated Groundwater: Field Test Experience", PTAC Environmental Forum and Technical Review, May 14-15, 2003.

"Solar Detoxification – Treatment of Contaminated Groundwater", SESCI 2003 Solar Society of Canada Conference, Queen's University, Kingston, Ontario, August 18 to 20, 2003.

Ethanol/BTEX Plume in Fractured Bedrock Model

Project: Attenuation of an Ethanol/BTEX Plume in Fractured Bedrock Model Undergoing Biostimulation

Publications:

Pamela Grande, M.Sc. Thesis, "Application of the Biostimulation Concept to Form a Biobarrier in a Fractured Rock Model to Remediate an Ethanol-BTEX Plume". To be Submitted in June 2004.

Presentations

Grande, P., Ross, N., Steer, H., and Barker, J. F. 2004. Biofilm Development in a Planar Fracture: Effects of a BTEX/Ethanol-Contaminated Groundwater, 39th Central Canadian Symposium on Water Pollution Research, February 10-11. Burlington, Ontario.

Grande, P., Ross, N., Steer, H., and Barker, J. F. 2004. Biofilm Development in a Planar Fracture: Effects of a BTEX/Ethanol-Contaminated Groundwater, 2004 US EPA/ NGWA Fractured Rock Conference: State of the Science and Measuring Success in Remediation, Portland, Maine September 13-15 (Submitted).

Standardization and Validation of Terrestrial Toxicity Test Procedures

Project: Standardization and Validation of Terrestrial Toxicity Test Procedures for Assessing Biological Effects in Hydrocarbon Contaminated Soil

Report

Assessment of the Biological Test Methods for Terrestrial Arthropods: Further Refinement of the Collombola Test Method Using Onychiurus Folsomi, ESG International Inc, 361 Southgate Drive, Guelph, Ontario, prepared for Method Development and Applications Section, Environment Canada, Environmental Technology Center, Ottawa, Ontario, February 2003.

Project: Assessment of Natural and Anthropogenic Impacts of Oil Sands Contaminants within the Northern River Basin.

Publications:

Bennett K. E., T. D. Williams, J. E. Smits, M. Wayland, and L. I. Bendell-Young. Submitted. Impact of oil sands based wetlands on the growth of Mallard (Anas platyrhynchos) ducklings.

Brownlee, B. G., G. A MacInnis, M. Alaee, A. Farwell, G. Dixon, and N. J. Bunce. 2002. Analysis of oil sands naphthenic acids by negative ion electrospray mass spectrometry. Extended abstract published in the Proceedings of the 50th ASMS Conference on Mass Spectrometry and Allied Topics, June 2-6, 2002, Orlando, Florida.

Conly, F.M., and R. W. Crosley. 1998. 1998 Field Program: Identification and Characterization of Natural Hydrocarbon Release from oil Sands Deposits in the Northern River Basins Area. Unpublished Report, Environment Canada, Prairie and Northern Wildlife Research Centre, Saskatoon Saskatchewan 16 pp.

Conly, F. M., J. V. Headley, and R. W. Crosley. 2002. Characterizing the sediment sources and natural hydrocarbon inputs in the lower Athabasca River, Canada. Journal of Environmental Engineering and Science 1:187-199.

Evans, M. S., B. Billeck, L. Lockhart, J. P. Bechtold, M. B. Yunker, and G. Stern. 2002. PAH sediment studies in Lake Athabasca and the Athabasca River ecosystem related to the Fort McMurray oil sands operations: sources and trends. Pages 365-374 in C. A. Brebbia, ed., Oil and Hydrocarbon Spills III. Modelling, Analysis and Control. WIT Press, Southampton.

Headley, J.V., C. Akre, F. M. Conly, K. M. Peru, and L. C. Dickson. 2001. Preliminary charaterization and source assessment of PAH in tributary sediments of the Athabasca River, Canada. Environmental Forensics 2:335-345.

Madill, R.E.A, M.T. Orzechowski, G. Chen, B.G. Brownlee and N.J. Bunce. 2001. Preliminary risk assessment of the wet landscape option for reclamation of oil sands mine tailings: Bioassays with mature fine tailings pore water. Environmental Toxicology 16:197-208.

Smits, J. E., M. Wayland, M. J. Miller, K. Liber, and S. Trudeau. 2000. Reproductive, immune and physiological endpoints in tree swallows on reclaimed oil sands mine sites. Environmental Toxicology and Chemistry 19:2951-2960.

Tetreault, G. R. 2002. Monitoring the aquatic environment in the Athabasca Oil Sands using reproductive responses in small-bodied fish. M.Sc. Thesis. University of Waterloo, Waterloo, Ontario.

Tetreault, G. R., M. E. McMaster, G. D. Dixon, and J. L. Parrott. 2002. Using reproductive endpoints in small forage fish species to evaluate the effects of Athabasca Oil Sands activities on the environment. Environmental Toxicology and Chemistry. In press.

Presentations, Conferences and Meetings:

Akre, C., J. V. Headley, F. M. Conly, K. M. Peru, and L. C. Dickson. 2002. Effects of weathering on the distribution of natural hydrocarbons in the Athabasca Oil Sands, Canada. The 23rd annual meeting of the Society of Environmental Contaminants and Toxicology, November 16-20, 2002, Salt Lake City, Utah.

Brownlee, B. G., G. A. MacInnis, R. E. A. Madill, M. T. Orzechowski, and N. J. Bunce. 1999. Toxicological studies on polycyclic aromatic compounds of importance to oil sands reclamation. Poster presentation. The 26th Annual Aquatic Toxicity Workshop, Edmonton, Alberta, October 2-6, 1999.

Brua, R. B., K. J. Cash, and J. M. Culp. 2002. Effects of exposure to naturally-occurring hydrocarbons on benthic macroinvertebrates of the Alberta oil sands region. Invited Presentation. Toxicology Centre, University of Saskatchewan, Saskatoon, SK.

Annex 2

Publications

Objective 1.3.3

Oil Sands Contaminants

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Cash, K.J. 1988. Investigations of the ecological impact of exposure to naturally-occurring hydrocarbons. Invited Presentation. CONRAD Aquatic Environmental Technical Advisory Group (CAETAG). Calgary, AB.

Cash, K.J. 1999. The PERD/NRBS research program. Invited Presentation. Regional Aquatic Monitoring Program. Fort McMurray, AB.

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Conly, F.M. 1999. Observations on sediment sources in the lower Athabasca River basin: Implications of natural hydrocarbon inputs from oil sand deposits. Oral presentation. The Scientific Meetings of the Canadian Geophysical Union, May 9-13, 1999, Banff, Alberta.

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Evans, M. S., L Lockhart, B. Billeck, P. Wilkinson, M. Yunker, J. P. Bechtold, and G. Stern. 2002. PAH sediment studies in Lake Athabasca and Great Slave Lake related to the Fort McMurray oil sands operations: sources, fates, and time trends. International Association for Great Lakes Research Conference, June 2-6, 2002, Winnipeg, Manitoba.

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Evans, M. S., W. L. Lockhart, D. C. G. Muir, J. Headley, and R. Bourbonniere. 1999. Long-range transport of PAHs, POPs, PCDDs and PCDFs to Great Slave Lake and Lake Athabasca, two of Canada's northern Great Lakes. The 20th annual meeting of the Society of Environmental Toxicology and Chemistry, November 14-18, 1999.

Evans, M. S., M. Yunker, L. Lockhart, B. Billeck, G. Stern, D. S. Jeffries, and S. Backus. 2000. Hydrocarbon sources and sinks in the Mackenzie River Basin: concentrations, composition, trends, and environmental concerns. 2000. The 21st meeting of the Society of Environmental Toxicology and Chemistry, November 12-16, 2000, Nashville, Tennessee.

Headley, J. V., C. Akre, K. M. Peru, F. M. Conly, and L. C. Dickson. 2001. Characterization of natural hydrocarbon release from oil sands deposits in tributaries of the Athabasca River Basin, Canada. The American Society of Mass Spetroscopy Conference, May 27-31, 2001, Chicago, Illinois.

Headley, J. V., F. M. Conly, L. C. Dickson, C. Akre, and K. M. Peru. 2000. Characterization of natural hydrocarbon release from oil sands deposits in tributaries of the Athabasca River Basin, Canada. The 27th Annual Aquatic Toxicity Workshop, October 1-4, St. John's, Newfoundland.

Annex 2

Publications

Objective 1.3.3

Oil Sands Contaminants

Lo, C.C., B.G. Brownlee and N.J. Bunce. Electrospray-mass spectrometric analysis of Athabasca Oil Sands naphthenic acids. Submitted to Analytical Chemistry.

Smits, J. E., A. Jeroski, R. Carter, and M. Wayland. 1999. Environmental health monitoring on Alberta oil sands wetland and terrestrial reclamation areas using upper trophic level birds. The 26th annual Aquatic Toxicity Workshop, October 2-6, 1999, Edmonton, Alberta.

Smits, J. E., A. Jeroski, R. Carter, M. Wayland, and K. Liber. 1999. Environmental health monitoring on Alberta oil sands reclamation areas using upper trophic level birds. Environmental Science and Technology Canada (ESTAC) Technology Day, November 15, 1999, Toronto, Ontario.

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Smits, J. E., M. J. Miller, C. Zimmer, and M. Wayland. 1998. Impacts of wetland contaminants on tress swallows and mallard ducklings. Year II Annual Report on Oil Sands Reclamation Studies. Environmental Science & Technology Alliance Canada, Suncor Inc, Syncrude Canada Ltd.

Smits, J. E., M. J. Miller, and M. Wayland. 1998. Passerine and waterfowl reproductive and immune status on reclaimed wetlands on oil sands mining sites. Wildlife Disease Association Conference, August 8-10, 1998, Madison, Wisconsin.

Smits, J. E. and M. Wayland. 1996. Immune function assay development in avian species to monitor environmental health of oil sands constructed wetlands. Canadian Oil Sands Network for Research and Development - Aquatic Technical Advisory Group Workshop, October 11-12, 1996, Calgary, Alberta.

Smits J. E., J. Yurach, C. Giocoli, G. Bortolotti, M. Wayland, and K. Liber. 2000. Environmental health assessment of active and reclaimed industrial sites and otherwise contaminated locations using upper trophic level birds. Environmental Science and Technology Alliance Canada (ESTAC) Technology Day, November13, 2000, Toronto, Ontario.

Strategic Intent 2: Strategic Direction 1: Objective 2.1.1

Objective 2.1.1

Support for the Development of Technological and Other Measures to Control and Reduce Emissions of Particulate Matters.

Characterization of Particulates and Precursors

Project: Characterization of Particulates and Precursors in Emissions

Publications

On the Source of Biological Marker Compounds in Mobile Source Particle Emissions

Gaseous & Particulate Matter Emissions from In-Use Light Duty Gasoline Motor Vehicles

On-Road Motorcycle Emissions- Characterisation of Particulate Matter & Gaseous Emissions

Evaluation of the EPA PART5 Model in Light of Recent Emissions Measurements
Emissions from Advanced Technology Vehicles

Emissions from Urban Buses

Annex 2

Publications

Objective 2.1.1

Presentations
6 presentations between 2000-2003

Gaseous and Particulate Matter Emissions from 70 In-use Light Duty Gasoline Motor Vehicles.

13th CRC – Urban Busses

13th CRC- Advanced Technology Vehicles

Characterization of Particles in Ambient Air

Project: Characterization of Particles in Ambient Air

Presentations
6 presentations between 2000 and 2003

1 presentation entitled "Organic Particles"

Objective 2.1.2

Strategic Intent 2: Strategic Direction 1: Objective 2.1.2

Advanced Fuels and Transportation Emissions Reduction

Engine Cold Start Efficiency

Project: Engine Cold Start Efficiency

Reports
Project: Measurement of Toxic Emissions from Ethanol/Gasoline Blend Fuels

The Phase 1 testing was reported by Environment Canada.

Project: Environmental Properties of Ether Fuels

Publications
Two Environment Canada publications have been released.

Objective 2.2.2

Strategic Intent 2: Strategic Direction 2: Objective 2.2.2

Fuel Cells, Electric and Hybrid Vehicles

Measurement of Toxic Emissions

Project: Measurement of Toxic Emissions from Fuel Cells, Electric, and Hybrid Vehicles

Publications
There are three draft reports in preparation for the 2003/04 work. One of these papers will be further developed into a technical paper under the SAE organization.

Objective 2.2.4

Strategic Intent 2: Strategic Direction 2: Objective 2.2.4

Optimization of the Energy Efficiency of Transportation Systems

St Lawrence Routing Management

Project: The St Lawrence Routing Management Support Model

Publications
Chassé, J. and F.-J. Saucier. 1998. Prévision des glaces pour l'estuaire et le golfe du Saint-Laurent. Nouvelles des Sciences, 9(15).

Annex 2

Publications

Objective 2.2.4

St Lawrence Routing Management

Roy, F., P. Pellerin, F.-J. Saucier, H. Ritchie. 1999. Coupled ice-ocean-atmosphere forecast in the Gulf of St. Lawrence, Canadian Meteorological and Oceanographic Society, Montreal.

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Presentations and Reports

BMT FTL, A Kindrick, "Prediction of ship winter transit in the Gulf of St Lawrence », May 2002:

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Comfort, G. B. Paterson, Y. Gong, L. Luznik., « Route forecasting studies for the Gulf of St Lawrence : pack ice measurement and analysis of ship transit data ». March 2000.

Corriveau, R. « Presentation at Shipping Federation of Canada », December 2000.

Enfotech Technical Services. « Improving Methodologies for Vessel Routing in the St Lawrence System : Analysis of Voyage performance of the Northern venture, Northern Progress and Northern Enterprise, Final report, March 2003.

Enfotech Technical Services. « Improving Methodologies for Vessel Routing in the St Lawrence System : Cost/Benefit Analysis Final report, March 2000.

Michaud, N. « Presentation at Canadian Coast Guard Marine Advisory Council , Laurentian region», October 2000.

Michaud, N. « Presentation at Groupe Desgagnés shipping Inc and St Lawrence Shipowners Association.», June 2000.

Michaud, N. « Presentation at the commanding officers workshop, December 2000.

Michaud, N. « Presentation at Canadian Marine Advisory Council (CMAC), Quebec, March 2004.

Michaud, N. « Presentation at Shipping Federation of Canada », November 2003.

Michaud, N. « Presentation at Shipping Federation of Canada », November 2002.

Michaud, N. « Presentation at Shipping Federation of Canada », December 2001.

Strategic Intent 3: Strategic Direction 2: Objective 3.2.4

Objective 3.2.4

Energy Management for Sustainable Communities

Energy from Waste Technologies

Project: Development of energy from waste technologies and other alternative technologies:
- Microturbines Development/Emission Research from Landfill Gas Improvement of Waste Management Decision-Making:
- Integrated Waste Management (IWM) Model
- Advanced Landfill Technology

No publications or presentations at this time.

Annex 2 Publications Objective 3.2.4

Clean Air OnLine

Project: Clean Air OnLine

Conferences:

Upwind Downwind Air Quality Conference 2004, Hamilton.
http://www.airquality.hamilton.on.ca/conf/2004/default.asp

Third Canadian Workshop on Air Quality: Pollutants Across Boundaries, Quebec City
http://aqworkshop.ec.gc.ca/default_e.html

Objective 4.3.3

Strategic Intent 4: Strategic Direction 3: Objective 4.3.3

Research, Development and Deployment of Industrial Separation and Refrigeration

Microwave-Assisted Processes

Project: Applications of Microwave-Assisted Processes (MAP™) To Solvent-less Synthesis and to Low Solvent, Energy-Efficient Extraction

Patent

J. R. J. Paré, J. M. R. Bélanger, and M. M. Punt, "Controlled Energy Density Microwave-Assisted Processes", Patent Application filed in the Patent Office of the USA, for the USA and issued as U.S. Patent No. 6,061,926.

Publications

J. A. García N., J. R. J. Paré, and J. M. R. Bélanger, "The Microwave-Assisted Processes (MAP™): Applications to the Extraction of Palm Oil", PALMAS, 21 (2), 371-384 (2000).

J. Dai, V. A. Yaylayan, G. S. V. Raghavan, J. R. J. Paré, and Z. Liu, "Multivariate Calibration for the Determination of Total Azadirachtin Related Limonoids and Simple Terpenoids in Neem Extracts Using Vanillin Assay", J. Ag. Food Chem. 49, 1169-1174 (2001).

J. R. J. Paré, J. M. R. Bélanger, B. Lesnik, R. Turpin, and R. Singhvi, "Final Evaluation of US EPA Method 3546: A Microwave-Assisted Process (MAP™) Method for the Extraction of Contaminants Under Closed-Vessel Conditions", Soil & Sediment Contamination 10 (4), 375-386 (2001).

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V. A. Yaylayan, J. R. J. Paré, G. Matni, and J. M. R. Bélanger, "MAP™: Microwave-Assisted Extraction of Fatty Acids and Py/GC/MS Analysis of Selected Insects", Natural Products Letters 15, 187-195 (2001).

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G. LeClair, K. Jankowski, J. M. R. Bélanger, J. R. J. Paré and M.-R. VanCalsteren, "Microwave-Assisted Diels-Alder Synthesis", Can. J. Chem., 79, 1906-1909 (2001).

V. A. Yaylayan, J. R. J. Paré, G. Matni, and J. M. R. Bélanger, MAP™: Microwave-Assisted Extraction of Cockroaches", Natural Products Letters 16, 123-127 (2002).

V. A. Yaylayan, M. Siu, J. M. R. Bélanger, and J. R. J. Paré, Microwave-Assisted PEGylation of Merrifield Resins, Tetrahedron Letters 43, 9023-9025 (2002).

J. M. R. Bélanger, M. J. Alfaro, F. C. Padilla, and J. R. J. Paré, "Influence of Solvent, Matrix Dielectric Properties, and Applied Power on the Liquid-Phase Microwave-Assisted Process (MAP™) Extraction of Ginger (*Zingiber Officinale*)", Food Research International 36, 499-504 (2003).

J.-H. Kwon, J. M. R. Bélanger, J. R. J. Paré, and V. A. Yaylayan, Application of the Microwave-Assisted Process (MAP^{TM}) to the Fast Extraction of Ginseng Saponins, Food Research International 36, 491-498 (2003).

J. M. R Bélanger, J.-H. Kwon, and J. R. J. Paré, Optimization of Microwave-Assisted Extraction (MAP^{TM}) for Ginseng Components by Response Surface Methodology, J. Ag. Food. Chem. 51, 1807-1810 (2003).

J.-H. Kwon, J. M. R. Bélanger, and J. R. J. Paré, Effect of Ethanol Concentration on Extraction Efficiency of Ginseng Saponins Using the Microwave-Assisted Process (MAP^{TM}), Int. J. Food Sci. Technol. 38, 615-622 (2003).

Presentations

J. R. J. Paré, Using Microwaves for the Extraction of Cocoa? Confidential industrial lecture, Singapore, February 2000 (invited lecture)

J. R. J. Paré and J. M. R. Bélanger, Microwave-Assisted Synthesis: A New Tool for the Organic Chemistry Practitioner, National Chung-Hsing University, Taichung, Taiwan February 2000 (invited lecture)

J. M. R. Bélanger, J. R. J. Paré, G. Hatfield, and S. Splinter, Microwave-Assisted Processes (MAP^{TM}): Extraction of Canola Oil, Microwave 2000: Sustainable Technology for the New Millennium and the 3rd Chinese Microwave Chemistry Symposium, Tianjin, China, May 2000 (invited lecture)

Z. Zhang, P. Devanahalli, J. M. R. Bélanger, S. J. Splinter and J. R. J. Paré, Scaling up the Microwave-Assisted Process (MAP^{TM}) as an Industrial Energy-Efficient Extraction Process through Mathematical Modeling and Pilot-Scale Experiments, Microwave 2000: Sustainable Technology for the New Millennium and the 3rd Chinese Microwave Chemistry Symposium, Tianjin, China, May 2000 (invited lecture)

J. R. J. Paré, J. M. R. Bélanger, and J.-F. Rochas, Bench-Scale Processing Equipment for Optimising Industrial Applications of the Microwave-Assisted Processes (MAP^{TM}), Microwave 2000: Sustainable Technology for the New Millennium and the 3rd Chinese Microwave Chemistry Symposium, Tianjin, China, May 2000

F. C. de Padilla, M. J. Alfaro, J. M. R. Bélanger and J. R. J. Paré, Liquid-Phase Microwave-Assisted Process (MAP^{TM}) Extraction of Cacao, IFT Annual Meeting, Atlanta, July 2000

J. R. J. Paré, MAP^{TM}: An Environment Canada Commercialization Success Story, FPPT Workshop, Ottawa, ON, June 2000 (invited lecture)

J. R. J. Paré and J. M. R. Bélanger, MAP^{TM}: Historical Notes and Perspectives, Business Lecture to NORAM Engineering, Vancouver, BC, August 2000 (invited lecture)

J. M. R. Bélanger and J. R. J. Paré, Microwave-Assisted Processes MAP^{TM}: An Energy Efficient "Green Processing Technology", International Symposium on Ecomaterials, Ottawa, ON, Canada, August 2000 (invited lecture).

J. R. J. Paré, J. A. Garcia, and J. M. R. Bélanger, Perpectivas Del Uso de Los Procesos Aistidos Por Microondas (MAP^{TM}) En Las Plantas de Beneficio de Fruto de Palma Y Datos Preliminares Del Uso de Los Procesos Asistidos Por Microondas (MAP^{TM}) Por La Extracción de Aceite de Palma, XIII Internacional Palm Oil Conference, Cartagena, Colombia, September 2000 (invited lectura).

J. R. J. Paré, Les micro-ondes dans le laboratoire, nouvelles perspectives, Département de Chimie, Université de Moncton, Moncton, NB, September 2000 (invited lecture).

The Microwave-Assisted Processes (MAP^{TM}): A Historical Perspective, COLACRO, February 2002, J. R. J. Paré (Invited Keynote Lecture).

A New Tool: The Dielectmeter, COLACRO IX, Cartagena, Colombia, February 2002, J. R. J. Paré, J. F. Rochas, J. Jacomino, F. N. Sánchez L. and J. M. R. Bélanger (poster).

Annex 2

Objective 4.3.3

Microwave-Assisted Processes

MAP Headspace: Preliminary Performance Evaluation of a Miniature Headspace cavity, COLACRO IX, Cartagena, Colombia, February 2002, J. R. J. Paré, F. N. Sánchez L., J. M. R. Bélanger, J. F. Rochas and K. Komori (poster).

Microwave-Assisted Processes (MAP™): Applications to Non-Conventional Processes, COLACRO IX, Cartagena, Colombia, February 2002, J. R. J. Paré, F. N. Sánchez L., J. M. R. Bélanger, J. F. Rochas and J. M. Jacomino (poster).

Microwave-Assisted Synthesis of Poly(ethyleneglycol) Modified Merrifield Resins. COLACRO IX, Cartagena, Colombia, February 2002, J. R. J. Paré, J. M. R. Bélanger, M. Siu, and V. A. Yaylayan (poster).

Synthesis and Py-GC/MS Analysis of Polymer-Linked Sugar-Amino Acid Conjugates. COLACRO IX, Cartagena, Colombia, February 2002, J. R. J. Paré, V. A. Yaylayan, M. Law, M. Tateyama, and J. M. R. Bélanger (poster).

Microwave-Assisted Gas-Phase Extraction (MAP-HS) in the Analysis of Volatile Components of Ginger, COLACRO IX, Cartagena, Colombia, February 2002, J. R. J. Paré, F. N. Sánchez L., J. M. R. Bélanger, M. J. Alfaro, and F. C. Padilla (poster).

Microwave-Assisted Processes (MAP™): Novel Equipment for the Automation of Gas-Phase Extraction and Analysis, COLACRO IX, Cartagena, Colombia, February 2002, J. R. J. Paré, J. M. R. Bélanger, F. N. Sánchez L., J. F. Rochas and K. Komori (poster).

Microwaves for Liquid- and Gas-Phase Extraction, Pre-Conference Course, COLACRO IX, Cartagena, Colombia, February 2002, J. R. J. Paré (invited lecturer).

Microwaves-Assisted Synthesis of Hybrid Polymers, 85th Canadian Society for Chemistry (CSC) Conference and Exhibition, Vancouver, BC, Canada, June 2002, J. R. J. Paré, J. M. R. Bélanger, M. Siu, and V. Yaylayan (oral presentation).

Microwaves-Assisted Processes (MAP™): Validation of Novel Miniature Headspace Cavity, 85th Canadian Society for Chemistry (CSC) Conference and Exhibition, Vancouver, BC, Canada, June 2002, J. R. J. Paré, J. M. R. Bélanger, F. N. Sanchez, J.-F. Rochas, and K. Komori (oral presentation).

Microwaves Assisted Gas-Phase Extraction (MAP-HS) in the Analysis of Volatile Components of Spices, 85th Canadian Society for Chemistry (CSC) Conference and Exhibition, Vancouver, BC, Canada, June 2002, J. R. J. Paré, F. N. Sanchez, and J. M. R. Bélanger (oral presentation).

J, M. R. Bélanger, J. R. J. Paré, F. Sanchez L., J.-F. Rochas, A New Apparatus Designed to Study the Interactions Between Matter and Microwaves", The 39th IUPAC Congress and 86th Conference of the Canadian Society for Chemistry, Ottawa, ON, Canada, August 2003.

J. R. J. Paré, J. M. R. Bélanger, X. Liao, F.Sanchez L., V. Yaylayan, A New Green Chemistry Tool for Monitoring Clean Processes in Real time, The 39th IUPAC Congress and 86th Conference of the Canadian Society for Chemistry, Ottawa, ON, Canada, August 2003.

Objective 5.1.1

Strategic Intent 5: Strategic Direction 1: Objective 5.1.1

Electricity from Renewable Energy Technologies

Solar Radiation

Project: EC Wind and Solar Energy Resource Assessment- Solar Radiation

Publications

McArthur, L.J.B. and E. Wu, 2003: Spectral Observations and Spectrometer Characterization. Comparative energy rating of silicon-based PV technologies under Canadian climatic conditions – Spectral Effects Final Meeting, December 8th, 2003 – CETC-Varennes, Varennes, PQ.

Annex 2

Publications

Objective 5.1.1

Wind Mapping

Project: Wind Mapping with Atmospheric Models

Publications

Article in TIMES magazine of Nov 18 2002: "The future is blowin' in the wind".

Article in Canada Research Horizons Spring 2003: "WEST wind blowing".

Presentations

CanWEA Congress of Sept 2002

Whitehorse International Wind Conference of May 2003

CanWEA Congress of Sept 2003

Objective 5.2.1

Strategic Intent 5: Strategic Direction 2: Objective 5.2.1

Characterization of Canadian Fuels and their Emissions (COFE)

Contaminants in Coal

Project: Environmental Contaminants in Coal and Coal Byproducts

Reports

Petrology of Feed Coals and Chars in ESP Fly Ashes as Related to Mercury Retained in Pulverized Coal-Fired Power Plants

Distribution of Carbon (Char) in ESP Ash and Its Role in Reduction of Mercury

Possible Link Between the Char Type and the Mercury Retained by Fly Ash in Coal-Fired Power Plants Burning Sub-Bituminous Coal in Alberta

Petrology of Sub-bituminous Coals from Alberta with Reference to their Inertinite Content

Mode of Occurrence of Trace Elements and Minerals in Coal

Chemical and Mineralogical Characteristics of Milled Coal, Ashes, and Stack-Emitted Material from Unit No. 5, Battle River Coal-Fired Power Station, Alberta, Canada

These reports have been prepared by the Geological Survey of Canada, Natural Resources Canada, Calgary.

Objective 5.2.2

Strategic Intent 5: Strategic Direction 2: Objective 5.2.2

Clean and Efficient Combustion Technologies for Large Utility Electricity Generation

Pollution from Stationary Combustion

Project: Prevention, Control and Mitigation of Pollution from Stationary Combustion Sources

Reports

"Mercury Control Technologies for Electric Utilities Burning Lignite Coal, Phase I, Bench- and Pilot-Scale Testing" prepared by EERC.

The SRC final report to be available after March 31, 2004.

"Application of IGCC Technology in Canada – Phases I through VII" prepared by CANMET Energy Technology Centre.

Annual reports prepared by CANMET Energy Technology Centre are held as "Protected Business Information" under confidentiality agreement with the project consortium partners.

Design and application of an On-Line Aerosol Laser Ablation Mass Spectrometer.

Annex 2

Publications

Objective 5.2.2

Pollution from Stationary Combustion

Real-Time Analysis and Modeling Techniques for Identifying the Origins of Urban Particulate Matter.

Long-Range Sources of Toronto Particulate Matter (PM2.5) Identified by Aerosol Laser Ablation Mass Spectrometry (LAMS).

Seasonal Particle Types in Toronto Identified by Aerosol Laser Ablation Mass Spectrometry (LAMS).

Comparison between Urban Toronto PM and Selected Materials: Aerosol Characterization Using Laser Ablation/Ionization Mass spectrometry.

On-line Analysis of Urban Particulate Matter Focusing on Elevated Wintertime Aerosol Concentrations.

Chemically-Assigned Classification of Aerosol Mass Spectra.

Aerosol Laser Ablation Mass Spectrometry of Suspended Powders from PM Sources and Its Implications to Receptor Modelling.

These reports have been prepared by the University of Toronto Department of Chemistry and Chemical Engineering.

Objective 5.2.3

Strategic Intent 5: Strategic Direction 2: Objective 5.2.3

CO_2 Capture and Storage

Coal Bed Methane – Characterization of Injected CO_2

Project: Coal Bed Methane Field Pilot – Characterization of Injected CO_2 and Impact on CBM

Conferences and Published Proceedings

Biogenic Methane Production from Coal with Implication for Carbon Dioxide Sequestration, Karen Budwill, Andrew Beaton, Marc Bustin, Karlis Muhlenbachs and W.D. Gunter, Proceedings of the 6th International Conference on GHG Control Technologies, Kyoto, Japan, 697-702 (2003)

Testing for CO2 Sequestration and Enhanced Methane Production from Coal, M. J. Mavor, W..D.Gunter, J.R. Robinson, D. H-S. Law and John Gale, SPE paper 75680, Presented at the SPE Gas Technology Symposium, May 30-April 2, Calgary, 14 p (2002)

CO_2-Enhanced Coalbed Methane Recovery Demonstration Pilot- A Case for Australia, S. Wong, K. MacLeod, M. Wold, W.D. Gunter, M.J. Mavor and J. Gale, Proceedings of the 2001 International CBM Symposium, Tuscaloosa, USA, May 14 to 18, 75-86 (2001).

Site Ranking for CO_2-Enhanced Coalbed Methane Demonstration Pilots, S. Wong, W.D. Gunter, and J. Gale, Proceedings of the 5th International Conference on GHG Control Technologies, Cairns, Australia, (Editors: D. Williams, B. Durie, P. McMullan, C. Paulson, Andrea Smith) CSIRO Publishing, 531-536 (2001).

Economics of Flue Gas Injection and CO_2 Sequestration in Coalbed Methane Reservoirs, S. Wong, W.D. Gunter, D. H.-S. Law and M.J. Mavor, Proceedings of the 5th International Conference on GHG Control Technologies, Cairns, Australia, (Editors: D. Williams, B. Durie, P. McMullan, C. Paulson, Andrea Smith) CSIRO Publishing, 543-548 (2001).

Enhanced Recovery of Coalbed Methane with Carbon Dioxide Sequestration– Selection of Possible Demonstration Sites, International Energy Agency Greenhouse Gas R&D Programme Report Number PH3/34, 178p. (2000).

Economics of CO_2 Sequestration in Coalbed Methane Reservoirs, S. Wong, W.D. Gunter, M.J. Mavor. Proceedings of SPE/CERI Gas Technology Symposium 2000, SPE 59785, April 3-5, Calgary, Alberta, 631-638 (2000).

Annex 2

Publications

Objective 5.2.3

Coal Bed Methane – Characterization of Injected CO_2

Updating Canadian Activities in Coalbed Methane, Ken Sinclair, W.D. Gunter, S. Wong. Proceedings of the Coalbed and Coal Mine Methane Conference in Denver, March 27-28, 9 pages (2000).

Deep Coalbed Methane in Alberta, Canada: A Fuel Resource with the Potential of Zero Greenhouse Gas Emissions, W.D.Gunter, T.Gentzis, B.A.Rottenfusser and R.J.H. Richardson, Energy Convers. Mgmt. 38 Suppl., S217-S222 (1997).

Comparison of Numerical Simulators for Greenhouse Gas Storage in Coalbeds, PartII: Flue Gas Injection, D,H,-S. Law, L.H.G. van der Meer and W.D. Gunter, Proceedings of the 6th International Conference on GHG Control Technologies, Kyoto, Japan, 563-568 (2003)

Numerical Simulator Comparison Study for Enhanced Coalbed Methane Recovery Processes: Part I Pure CO2 Injection. D. H-S. Law, W.D. Gunter and L.G.H. van der Meer, SPE 75669, Presented at the SPE Gas Technology Symposium, May 30-April 2, Calgary, 12p (2002)

Comparison of Numerical Simulators for Greenhouse Gas Sequestration in Coal Beds Part I: Pure Carbon Dioxide Injection, D.H.-S. Law, L.G.H. van der Meer, and W.D. Gunter, Proceedings of 1st National Conference on Carbon Sequestration, Washington, DC., May 14-17, 15 p. (2001)

Modelling of Carbon Dioxide Sequestration in Coal Beds: A Numerical Challenge, D.H.-S. Law, L.G.H. van der Meer, M.J. Mavor and W.D. Gunter, Proceedings of the 5th International Conference on GHG Control Technologies, Cairns, Australia, (Editors: D. Williams, B. Durie, P. McMullan, C. Paulson, Andrea Smith) CSIRO Publishing, 537-542 (2001).

Reports

Adsorption Isotherm Study of Sample 500-C2, From Well 102/02-19-028-24W4, Alberta, Canada; Terratek Inc. Report. 30 pages as well as digital spreadsheets.

Adsorption Isotherm Study of Sample 501-C2, From Well 102/06-13-023-26W4, Alberta, Canada; Terratek Inc. Report. 30 pages as well as digital spreadsheets.

Workshops and Presentations:

Hughes, J.D., 2001; Coal: Energy for the 21st Century; Canadian Institute of Mining, Metallurgy and Petroleum – Economics Section; Abstract and Luncheon Presentation, Calgary, Alberta, November, 2001.

Hughes, J.D., 2001; National Coal Inventory: Coal, Coalbed Methane and CO_2 Storage Capacity Assessment; presentation at the Annual Conference of the Canadian Coalbed Methane Forum, Calgary, Alberta, October, 2001.

Hughes, J.D., 2001; National Assessment of Deep Coal Seams in Canada for the Storage of CO_2; presentation to meeting of Federal and Provincial Energy ADM's, Vancouver, British Columbia, July, 2001.

Objective 6.1.1

Strategic Intent 6: Strategic Direction 1: Objective 6.1.1

Climate Change Impacts on the Energy Sector

Historical and Future Climate

Project: Historical and Future Climate for the Assessment of Energy Sector Impacts in Canada

A Synthesis Report of the Web-Workshop on Climate Scenarios

A report entitled " Climate Change and the Canadian Energy Sector: Report on Vulnerability, Impact and Adaptation"

Presentation made in the World Climate Conference in Moscow, September 29-October 3, 2003.

Pollution Probe Energy Workshop 22 March 2004, Toronto

Annex 2

Publications

Objective 6.1.1

Climate Changes in the Canadian Inland Seas Watershed

Project: Impacts of Climate Changes in the Canadian Inland Seas Watershed on the Canadian Energy Sector

Publications (Peer-reviewed scientific papers)

Faucher, M., D. Caya, F.J. Saucier, and R. Laprise (in revision) Interaction between the atmosphere and the ocean over the Gulf of St. Lawrence, Atmos.-Ocean.

Gachon P., Laprise R., Zwack P. and Saucier, F.J., 2002. The direct and indirect effects of surface forcings in the development of a model-simulated polar low in the Hudson Bay. Tellus A 55 (1): 61-87.

Gachon, P., and F. J. Saucier, (in revision). Sensitivity study of the effects of surface oceanic conditions in the Gulf of St. Lawrence on the regional atmospheric circulation in winter time, Atmosphere-Ocean.

Pellerin, P., H. Ritchie, F.J. Saucier, F. Roy, S. Desjardins, M. Valin, V. Lee (submitted to Monthly Weather Review) Impact of a two-way coupling between an atmospheric and ocean-ice model over the Gulf of St. Lawrence.

Saucier, F. J., F. Roy, D. Gilbert, P. Pellerin, and H. Ritchie (in press). Modelling the formation and circulation processes of water masses and sea ice in the Gulf of St. Lawrence, Canada, J. Geophys. Res.

Saucier, F.J., S. Senneville, S. Prinsenberg, F. Roy, P. Gachon, D. Caya, and R. Laprise (submitted to Climate Dynamics). Modeling the ice-ocean seasonal cycle in Hudson Bay, Foxe Basin and Hudson Strait, Canada.

Wang, Jia, M. Ikeda and F.J. Saucier, 2003. A theoretical, two-layer, reduced-gravity model for descending dense water flow on continental shelves/slopes. J. Geophys. Res. Vol. 108, No. C5.

Scientific reports and thesis

Bourgault, D. 2001. The response of an estuary to changes in river flow. Ph. D. Thesis, McGill, Montreal.

Charpentier, D., 2002. Coupled atmosphere-ocean seasonal cycle modeling for the Gulf of St. Lawrence, Ms. Thesis, Université du Québec à Montréal

Faucher, M., D. Caya, F. J. Saucier, and R. Laprise, 2002. Regional atmosphere-ocean-ice climate modelling over Eastern Canada, Ph.D. Thesis, UQAM.

Faucher, M., Caya, D., Saucier F.J. and Laprise, R., 2002. Interaction between atmosphere and ocean-ice regional models over the Gulf of St. Lawrence area, Canada. Research activities in atmospheric and oceanic modelling, World Meteorological Organization TD no. 1105, Report No. 32, Chap. 7, 9-10.

Gachon, P., F.J. Saucier, and R. Laprise, 2002. Evaluation of summer-time near-surface temperature and wind fields over Hudson Bay in a regional atmospheric model, Research activities in atmospheric and oceanic modelling, World Meteorological Organization –TD-no. 1105, Report No. 32, Chap. 5, p. 13-14;

Gachon P., F. J. Saucier, M. Faucher, and R. Laprise, (in press). Development of an atmosphere-ocean-sea ice coupled regional model in the Gulf of St. Lawrence, in Research activities in atmospheric and oceanic modelling, World Meteorological Organization -TD.

Galbraith, P., Saucier, F.J., Michaud, M., Lefaivre, D., Corriveau, R., Roy, F., Pigeon, R. and Cantin, 2002. Shipborne monitoring of near-surface temperature and salinity in the Estuary and Gulf of St. Lawrence, AZMO Bulletin AZMP (Therriault, J.-C. et Devine, L., eds.), 2 :26-30.

Goldstein, J. and J. Milton, 2003. Regional climate scenarios set development for hydrological impact studies. In : Preprints CD-Rom of the 14th Symposium on Global Change and Climate Variations, February 9-13, 2003, Long Beach, California. American Meteorological Society, Boston, USA, 5 pp.

Goldstein, J. M. Mirza, D. Etkin, and J. Milton, 2003. Hydrologic assessment: application of extreme value theory for climate extreme scenarios construction. In : Preprints CD-Rom of the 14th Symposium on Global Change and Climate Variations, February 9-13, 2003, Long Beach, California. American Meteorological Society, Boston, USA, 5 pp.

Lam K.H. (2002). Lien entre le climat et l'écoulement des rivières dans le nord-est du Québec, Rapport scientifique, Service météorologique du Canada - Région du Québec, Avril 2002, 107 pp

Senneville, S., F.J. Saucier, P. Gachon, R. Laprise, and D. Caya, 2002. Development of a Coupled Ice-Ocean Model of Hudson Bay, in Research activities in atmospheric and oceanic modelling, World Meteorological Organization –TD-no. 1105, Report No. 32, Chap. 8, p. 23-24;

Scientific presentations /invited conferences (non-exhaustive list)

Faucher, M., D. Caya, F. J. Saucier, and R. Laprise, 2001. Regional atmosphere-ocean-ice climate modelling over Eastern Canada, American Meteorological Society (AMS) Conference on Polar Meteorology and Oceanography and 11th Conference on Interaction of the Sea and Atmosphere, 14-18 May 2001, San Diego (California, USA).

Gachon, P., F. J. Saucier, and R. Laprise, 2001. Atmosphere-ocean-ice interaction processes in the Gulf of St. Lawrence : numerical study with a coupled model. 6th American Meteorological Society (AMS) Conference on Polar

Meteorology and Oceanography and 11th Conference on Interaction of the Sea and Atmosphere, 14-18 May 2001, San Diego (California, USA).

Goldstein J., 2001. Methodology for scenario elaboration for the energy sector, Présentation faite à des représentants d'Hydro-Québec et de l'Institut de recherches électriques du Québec, 4 octobre 2001

Lam K.H., 2001. Lien entre le climat et l'hydraulicité, Présentation faite à des représentants d'Hydro-Québec et de l'Institut de recherches électriques du Québec, 4 octobre 2001

Vigeant, G., Changement climatique et le Saint-Laurent, St-Hubert, January 29-30, 2002.

Saucier, F.J., Senneville, S., and F.J. Saucier, 2002. Development of coupled sea-ice model of Hudson Bay, Climate variability and predictibility workshop. Victoria Feb. 25-26.

Smith, G.C., F.J. Saucier, and D. Straub, 2002. Winter Sources of Mixing in Northern Shelf Seas. Canadian Climate Variability Research Network Workshop, Victoria, Feb. 25-26.

Goldstein J. ,2002. Climate Scenario and Climate Change Scenario construction using GCMs output based method, stochastic weather generator (LARS) and statistical downscaling model (SDSM) for St.Lawrence River Region, Presented to the IJC Lake Ontario-St.Lawrence River Study Climate Change Meeting, Ottawa, April 17th, 2002

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Climate Changes in the Canadian Inland Seas Watershed

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Project: Climate Change and Offshore Design Criteria

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Additionnal presentations:
October 2003: presentation of results to International Oil and Gas Producers (OGP) MetOcean Committee, San Francisco

January 2003: presentation of results to PERD CCIES Workshop, Toronto.

October 2002: presentation of results to International Oil and Gas Producers (OGP) MetOcean Committee, Banff.

March, 2002: presentation to Oceanology International on "Marine Climate Variability and its Impact on Ocean and Coastal Engineering", London, UK

January, 2002: presentation to CLIVAR "Workshop on Advances in the Use of Historical Marine Climate Data", Boulder, CO

April 2001: presentation of results to International Oil and Gas Producers (OGP) MetOcean Committee, London, UK.

Evolving Ice Conditions

Project : Impacts of Evolving Ice Conditions on the Energy Sector

Publications
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Project: Critical Aspects of Change in Sea Ice Cover on Energy Production

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FIRE III/SHEBA

Project: Canadian Participation in FIRE III/SHEBA

Publications
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Isaac, G. A., S. G. Cober, I. Gultepe, A. V. Korolev, F. S. Boudala, and M. E. Bailey, 2002: Particle spectra in stratiform clouds. Preprints in CD, AMS 11th Conference o Cloud Physics, Ogden, USA, 3-7 June 2002. 7 pp.

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Annex 2

Publications

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Cold-Regions Hydrologic Processes and Extreme Events

Project: Climate Change Impacts on Cold-Regions Hydrologic Processes and Extreme Events Associated with the Hydro-Electric and Oil/Gas Industries in Western and Northern Canada

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Peters, D.L., Bonsal, B.R., Lacroix, M.P. and Prowse, T.D. 2003b. Potential change to the precipitation minus evaporation index in northern Canada during the 21st century. In: Abstracts of the 29th Scientific Meeting of the Canadian Geophysical Union, May 10-14, Banff, Canada.

Peters, D.L., Bonsal, B.R., Lacroix, M.P. and Prowse, T.D. 2003c. Precipitation minus evaporation index in northern Canada: 1961-90 vs. 2070-99. In: Abstracts of the On the Edge meeting of the Canadian Association of Geographers (CAG), May 28-31, Victoria BC, Canada.

Pietroniro, A., Conly, M., Mackay, M., Soulis, E.D., Kouwen, N., Leconte, R., Bullas, J., Beltaos, S., Prowse, T.D., Bonsal, B., Martz, L. and Peters, D.L. 2002. Evaluation of eco-sensitive operational strategies for the WAC Bennett dam relative to hydro-climatic relationships affecting northern deltas. Proceedings of the 7th Mackenzie Annual Scientific Meeting of the Mackenzie GEWEX Study (MAGS), November 7-9, 2001 (edited by P. di Cenzo), Hamilton, ON, p. 146-151.

Pohl, S., P. Marsh, A. Pietroniro, and G. Liston. 2003. Modelling spatial variability of snowmelt in an arctic catchment. Proceedings, 29th Annual Meeting of the Canadian Geophysical Union, Banff, Alberta, May 10-14/03.

Prowse, T.D. 2003. Climate impacts on northern aquatic systems. In: Abstracts of the On the Edge meeting of the Canadian Association of Geographers (CAG), May 28-31, Victoria BC, Canada.

Prowse, T.D. and Beltaos, S. 2002. Climatic control of river-ice hydrology: a review. Hydrological Processes, 16(4): 805-822.

Prowse, T.D. and Carter, T. 2002. Significance of ice-induced hydraulic storage to spring runoff: a case study of the Mackenzie River. Hydrological Processes, 16(4): 779-788.

Prowse, T.D. and Culp, J.M. 2003. Ice breakup: a neglected factor in river ecology. Canadian Journal of Civil Engineering, 30:128-144.

Prowse, T.D., Bonsal, B.R., Lacroix, M.P. and Beltaos, S. 2002a. Trends in river-ice breakup and related temperature controls. Proc. 16th IAHR International Symposium on Ice, Dunedin, New Zealand, December 2-6, 2002, Vol. 3: 64-71.

Prowse, T.D., Bonsal, B.R., Beltaos, S. and Lacroix, M.P. 2002b. Mid-winter warming: An increasing source of hydrologic extreme events? In: Abstracts of the 28th Scientific Meeting of the Canadian Geophysical Union, May 18-21, Ottawa, Canada.

Prowse, T.D., Peters, D., Beltaos, S., Pietroniro, A., Romolo, L., Töyrä, J., and Leconte, R. 2002c. Restoring ice-jam floodwater to a drying delta ecosystem. Water International, 27(1): 58-69.

Prowse, T.D., Peters, D., Beltaos, S., Pietroniro, A., Romolo, L., Töyrä, J. and Leconte, R. 2002d. Restoring ice-jam floodwater to a drying delta ecosystem. International Water Resources Association, Water International, 27(1): 58-69.

Romolo, L.A., Prowse, T.D., Blair, D., Bonsal, B. and Martz, L.W. 2002. Synoptic controls of snow pack accumulation in the upper reaches of the Peace River basin, 1963-1996. In: Abstracts of the 28th Scientific Meeting of the Canadian Geophysical Union, May 18-21, Ottawa, Canada.

Romolo, L.A., Prowse, T.D., Blair, D., Bonsal, B. and Martz, L.W. 2002. The synoptic controls of snow ablation in the upper reaches of the Peace River basin, 1963-1996. In: Abstracts of the 28th Scientific Meeting of the Canadian Geophysical Union, May 18-21, Ottawa, Canada.

Rouse, W. R., A.K. Eaton, R.M. Petrone, L.D. Boudrea, P. Marsh, and T.J. Griffis. 2003a. Seasonality in the surface energy balance of Tundra in the lower Mackenzie River basin. Jounal of Hydrometeorology, 4, 673-679.CAGES Special Issue

Rouse, W. R., E. M. Blyth, R. W. Crawford, J. R. Gyakum, J. R. Janowicz, B. Kochtubajda, H. G. Leighton, P. Marsh, L. Martz, A. Pietroniro, H. Ritchie, W. M. Schertzer, E. D. Soulis, R. E. Stewart, G. S. Strong, and M. K. Woo. 2003b. Energy and Water Cycles in a High Latitude, North-Flowing River System: Summary of results from the Mackenzie GEWEX Study - Phase I. Bulletin of the American Meteorological Society, January, 73-87.

Stewart, R. E., N. Bussieres, Z. Cao, H. R. Cho, D. Hudak, B. Kochtubajda, H. Leighton, P. Y. T. Louie, M. D. Mackay, P. Marsh, G. Strong, K.K. Szeto, and J.E. Burford. 2002. Hydrometeorological features of the Mackenzie basin climate system during the 1994/1995 water year: A period of record low discharge. Atmosphere-Ocean, 4, 257-278.

Töyrä, J., Pietroniro, A., Martz, L.W. and Prowse, T.D. 2002. A multi-sensor approach to wetland flood monitoring. Hydrological Processes, 16(8): 1569-1581.

In addition to many of the science presentations noted in the above publication list, other meetings/activities included:

P. Marsh presented an invited talk to a DIAND/Water Resources sponsored meeting in Calgary on preparing for natural gas development in the Mackenzie Valley and Delta. In addition, he also attended an DIAND meeting in Yellowknife on research gaps related natural gass development in the Mackenzie Valley/Delta region.

T. Prowse continues to be involved in the international Arctic Climate Impact Assessment (ACIA) to be a lead author of a chapter dealing with climate changes on the hydrology and cryosphere of the northern latitudes. A specific area that he has authored deals with changes in northern hydrologic regimes and freshwater ice covers; the foci of two of the PERD themes in this study.

Annex 2
Publications
Objective 6.1.1

Climate of Western Canada

Project: Critical Aspects of the Climate of Western Canada for the Energy Industry

Publications

Liu, Jinliang, Stewart, Ronald E. 2003: Water Vapor Fluxes over the Saskatchewan River Basin. Journal of Hydrometeorology: Vol. 4, No. 5, pp. 944–959.

Liu, Jinliang, Stewart, Ronald E., Szeto, Kit K. 2004: Moisture Transport and Other Hydrometeorological Features Associated with the Severe 2000/01 Drought over the Western and Central Canadian Prairies. Journal of Climate: Vol. 17, No. 2, pp. 305–319.

Liu J., K.K. Szeto, R.E. Stewart, 2003: Precipitation recycling over the Canadian Prairies (to be submitted to Atmos.-Ocean).

MacKay, M. D., Seglenicks, F., Verseghy, D., Soulis, E. D., Snelgrove, K. R., Walker, A., Szeto, K. 2003: Modeling Mackenzie Basin Surface Water Balance during CAGES with the Canadian Regional Climate Model. Journal of Hydrometeorology: Vol. 4, No. 4, pp. 748–767.

Szeto, K.K., 2003: Atmospheric enthalpy budgets for the Mackenzie River Basin with application to understanding the interannual variability of the basin winter temperatures (submitted to the J. Climate).

Szeto, K.K., H. Tran, M.D. Mackay, R.E. Stewart, R. Crawford, A. Betts: Characterization of the Water and Energy Budgets for the Mackenzie River Basin (to be submitted to J. Hydrometeorology).

Szeto, K., and M. Mackay: Critical Aspects of the Climate of Western Canada for the Energy Industry. PERD Climate Change Workshop. Toronto, On., Jan., 2003.

Szeto, K.K.: Energy budget studies - Scientific background, progress and issues. MAGS WEBS Workshop, Toronto, On., May, 2002. (Invited)

Szeto, K.K.: Northern water and energy cycles. 4th CSA Atmospheric Environment Workshop, London, On., May 2002. (Invited).

Szeto, K.K., and R.E. Stewart: WEBS in MAGS. GHP WEBS Workshop, GISS, N.Y., N.Y., September, 2002.

Szeto, K.K.: Atmospheric enthalpy budget for the Mackenzie River Basin. Proceedings 8th Annual Scientific Meeting for the Mackenzie GEWEX Study (MAGS). Jasper, Ab., Nov. 2002.

Szeto, K.K.: Coupled modelling in MAGS. GEWEX SSG Meeting, Bangkok, Thailand, Jan., 2003. (Invited)

Szeto, K.K.: WEBS in MAGS. 9th Annual Scientific Meeting for the Mackenzie GEWEX Study (MAGS). Montreal, Que, Nov. 2003.

Woo, H., J. Gykum, F. Hicks: Mackenzie GEWEX Program and the Mackenzie Gas Pipeline. Mackenzie Gas Pipeline Workshop. 2003.

Annex 2
Publications
Objective 6.1.1

Snow Water Equivalent Variations

Project: Snow Water Equivalent Variations in Western Canada and Climate Change Related Impacts for Hydropower Production

Publications

Derksen, C., A. Walker and B. Goodison (2003): A comparison of 18 winter seasons of in situ and passive microwave-derived snow water equivalent estimates in Western Canada. Remote Sensing of Environment, Vol. 88, 271-282.

Cloud Cover over North America

Project: Changes in Cloud Cover over North America for Solar Energy Development in Canada

Impacts of aerosols on the cloudiness, surface solar radiation and precipitation in North America has been finished and reviewed by scientists in our Branch. It will be submitted to a peer-reviewed journal very soon.

The manuscript of second paper The future cloudiness, radiation and precipitation in North America under IPCC A1 scenario will be finished in the near future.

Climate Change

Project: Climate Change Impacts on the Energy Sector

Publications:

Caires, S. and Sterl, A., 2003. Validation of ocean wind and wave data using triple collocation. J. Geophys. Res., 108(C3), 3098, doi:10.1029/2002JC001491.

Caires, S. and Sterl, A., 2003. On the estimation of return values of significant wave height data from the reanalysis of the European Centre for Medium-Range Weather Forecasts. Proc. of the European Safety and Reliability Conf., Maastricht, The Netherlands, 15-18 June 2003.

Lozano, I., and V.R. Swail, 2002. The link between wave height variability in the North Atlantic and the storm track activity in the last four decades. Atmosphere-Ocean 40 (4), 377-388.

Wang, X.L. and V.R. Swail, 2001. Changes of extreme wave heights in Northern Hemisphere oceans and related atmospheric circulation regimes. J. Climate, 14, 2204-2221.

Wang, X.L., F.W. Zwiers and V.R. Swail, 2004. North Atlantic Ocean wave climate change scenarios for the 21st century. Accepted in J. Climate.

Wang, Xiaolan L., V.R. Swail, 2002. Trends of Atlantic Wave Extremes as Simulated in a 40-Yr Wave Hindcast Using Kinematically Reanalyzed Wind Fields. J. Climate, 15(9), 1020–1035.

Yell and, M. J., B. I. Moat, R. W. Pascal and D. I. Berry , 2002: CFD model estimates of the airflow over research ships and the impact on momentum flux measurements. Journal of Atmospheric and Oceanic Technology Vol. 19, No. 10, pp. 1477–1499.

Conference Papers and Presentations:

Berek, G., 2002. Effects of Sampling Rate on Extreme Value Analysis of Wave Height. Proceedings 7th International Workshop on Wave Hindcasting and Forecasting, 21-25 October 2002, Banff, Alberta.

Caires, S., A. Sterl, J.-R.Bidlot, N. Graham and V. Swail, 2002. Climatological Assessment of Reanalysis Ocean Data. Proceedings 7th International Workshop on Wave Hindcasting and Forecasting, 21-25 October 2002, Banff, Alberta.

Caires, S., and A. Sterl, 2003. The ERA-40 Wind and Wave Data. CLIMAR-II: Second JCOMM Workshop on Advances in Marine Climatology, Brussels, Belgium, November 17-22, 2003.

Annex 2

Publications

Objective 6.1.1

Climate Change

Hogg, W.D., and V. R. Swail, 2002. Effects of Distributions and Fitting Techniques on Extreme Value Analysis of Modelled Wave Heights. Proceedings 7th International Workshop on Wave Hindcasting and Forecasting, 21-25 October 2002, Banff, Alberta.

Orelup, E.A., A. Niitsoo and V. J. Cardone, 2002. North Atlantic Wave Climate Extremes and their Variability. Proceedings 7th International Workshop on Wave Hindcasting and Forecasting, 21-25 October 2002, Banff, Alberta.

Swail, V.R., Xiaolan L. Wang and Andrew Cox, 2002. The Wave Climate of the North Atlantic - Past, Present and Future; . Proceedings 7th International Workshop on Wave Hindcasting and Forecasting, 21-25 October 2002, Banff, Alberta.

Thomas, B., and V. Swail, 2002. Methods to Reduce Biases Between Wind Speeds from Ships and Buoys. Proceedings 7th International Workshop on Wave Hindcasting and Forecasting, 21-25 October 2002, Banff, Alberta.

Thomas, B., and V.R. Swail, 2003. Methods to Homogenize Wind Speeds From Ships and Buoys. CLIMAR-II: Second JCOMM Workshop on Advances in Marine Climatology, Brussels, Belgium, November 17-22, 2003.

Wang, X.L., and V.R. Swail, 2002. North Atlantic ocean wave climate change scenarios. AMS 13th Symposium on Global Change and Climate Variations, January 14-18, 2002, Orlando, FL.

Presentations:
October 2003: presentation of results to International Oil and Gas Producers (OGP) MetOcean Committee, San Francisco

January 2003: presentation of results to PERD CCIES Workshop, Toronto.

October 2002: presentation of results to International Oil and Gas Producers (OGP) MetOcean Committee, Banff.
March, 2002: presentation to Oceanology International on "Marine Climate Variability and its Impact on Ocean and Coastal Engineering", London, UK

January, 2002: presentation to CLIVAR "Workshop on Advances in the Use of Historical Marine Climate Data", Boulder, CO

April 2001: presentation of results to International Oil and Gas Producers (OGP) MetOcean Committee, London, UK.

Toronto-Niagara Region

Project: Climate and Energy in the Toronto-Niagara Region (Integration of Science and Policy)

Upcoming March 22, 2004 workshop.

Pending peer-reviewed paper in international Weather and Forecasting journal.

Presentations at national and international conferences (May 2003, July 2003).

Annex 2

Publications

Objective 6.2.1

Strategic Intent 6: Strategic Direction 2: Objective 6.2.1

Enhancement of Greenhouse Gas Sinks

Terrestrial CO_2 Sources and Sinks

Project: Estimation of Terrestrial CO_2 Sources and Sinks in Canada

Publications and Reports

On the CO_2 exchange between the atmosphere and the biosphere: The role of synoptic and mesoscale processes, Tellus (in press), 2004.

Unaccounted link between global free troposphere and terrestrial sources/sinks of CO_2: Synoptic scale vertical transport in near-front zone, MSC Baseline Report, 2003.

Presentations

Frequent aircraft vertical profiling as a tool for studies of synoptic variability in the atmospheric boundary layer, 12th WMO Meeting of CO_2 Experts, Toronto, 15-17 September, 2003.

On the CO_2 exchange between the atmosphere and the biosphere: The role of synoptic and mesoscale processes, AGU Fall Meeting, San Francisco, 8-12 December, 2003.

Wetlands in the Forest Context

Project: Wetlands in the Forest Context-Carbon Sink Potentiel

Publications

Beall, F.D., R.A. Bourbonniere and I.F. Creed (2003). Susceptibility of forested wetlands carbon budgets to climate change and variability. Pres. PERD Greenhouse Gas Sources & Sinks Wks., Downsview, ON, Jan. 20-21. ABSTRACT.

Beall, F.D., R.G. Semkin and D.S. Jeffries. 2001. Trends in the output of first-order basins at the Turkey Lakes Watershed, 1982 – 96. Ecosystems **4**: 514 – 526.

Bender, T. (2000). Effect of drought on temperate wetland carbon emissions. McMaster University, School of Geography and Geology, BSc. Thesis, 31pp.

Bourbonniere, R.A., K. Edmondson, F. Dunnett, K. Livingston, S. Kaufman and J.M. Waddington (2003). DOM character responds to variable hydrologic flowpaths in a temperate forested swamp. Pres. CGU Ann. Mtg., Banff, AB, May 10-14, ABSTRACT.

Bourbonniere, R.A., K. Livingston, J.M. Waddington, K. Edmondson, F. Dunnett, S. Kaufman, M. Young and B. Branfireun (2002). Dynamics of dissolved organic carbon export from a temperate swamp. Pres. CGU Annual Mtg., Banff, AB, May 18-21, ABSTRACT.

Chahil, P. (2001). The effect of drought and flooding conditions on the inter-annual variability of carbon emissions from a temperate wetland. McMaster University, School of Geography and Geology, BSc.Thesis, 35pp.

Livingston, K. (2001). Spatial and temporal variability of dissolved organic carbon export from a temperate swamp. McMaster University, School of Geography and Geology, BSc. Thesis, 32pp.

Waddington, J.M., R. Bourbonniere, T. Bender, K. Edmondson, and F. Dunnett (2002). Hydrogeomorphic controls on CO_2 and CH_4 emissions from a temperate swamp. Pres. CGU Annual Mtg., Banff, AB, May 18-21, ABSTRACT.

Warren, F.J., J.M. Waddington, R.A. Bourbonniere and S.A. Day (2001). Effect of drought on sulphate dynamics in a temperate swamp. Hydrological Processes **15**:3133-3150.

Annex 2

Publications

Objective 6.2.1

Wetlands in the Forest Context

Submitted papers

Beall, F.D., R.A. Bourbonniere and I.F. Creed (Subm). Topographic distribution of soil respiration in northern hardwood forests. For Pres. at CGU/AGU Joint Assembly, Montreal, QC, May 17-21 2004. ABSTRACT.

Bourbonniere, R.A., F.D. Beall and I.F. Creed (Subm). Topographic distribution of carbon dioxide effluxes: Moving beyond wetlands in forested landscapes. Submitted to Geophysical Research Letters.

Bourbonniere, R.A., I.F. Creed, R. Kapila and J. Collins (Subm) Hot stuff: Lability of forest floor DOM to aerobic degradation. For Pres. at CGU/AGU Joint Assembly, Montreal, QC, May 17-21 2004. ABSTRACT.

Wetlands in the Agricultural Context

Project: Wetlands in the Agricultural Context-Carbon Sink Potential

Publications

Bourbonniere, R.A., K. Livingston, J.M. Waddington, K. Edmondson, F. Dunnett, S. Kaufman, M. Young and B. Branfireun (2002). Dynamics of dissolved organic carbon export from a temperate swamp. Pres. CGU Annual Mtg., Banff, AB, May 18-21, ABSTRACT.

Euliss, N.H., R.A. Gleason, A. Olness, R.L. McDougal, H.R. Murkin, R.D. Robarts, R.A. Bourbonniere and B.G. Warner (2002a). Prairie wetlands of North America important for carbon storage. Invited Pres. SWS Annual Mtg., Lake Placid, NY, Jun. 2-7, ABSTRACT.

Euliss, N.H., R.A. Gleason, A. Olness, R.L. McDougal, H.R. Murkin, R.D. Robarts, R.A. Bourbonniere and B.G. Warner (2002b). Prairie wetlands of North America important for carbon storage. Pres. Symp. "Natural Resource Management to Offset Greenhouse Gas Emissions", Raleigh, NC, Nov. 19-21, ABSTRACT.

McDougal, R.L. et al. (2003). Wetland carbon cycles in agro-ecosystems. Pres. PERD Sources and Sinks Wks. Downsview, ON, Jan. 20-22.

Waddington, J.M., R. Bourbonniere, T. Bender, K. Edmondson, and F. Dunnett (2002). Hydrogeomorphic controls on CO_2 and CH_4 emissions from a temperate swamp. Pres. CGU Annual Mtg., Banff, AB, May 18-21, ABSTRACT.

Carbon Sequestration in a Boreal Deciduous Forest

Project: Impact of Variability and Climate Change on Carbon Sequestration in a Boreal Deciduous Forest

Publications

Arain, M.A., Black, T.A., Barr, A.G., Griffis, T.J., Morgenstern, K and Nesic, Z., 2003. Year round observations of the energy and water vapour fluxes above a boreal black spruce forest. Hydrological Processes 17: 3581-3600.

Barr, A.G., T.A. Black and E.H. Hogg. Submitted. The effect of seasonal changes in the leaf area index on radiation, water vapor, and carbon dioxide fluxes above a boreal aspen forest. Submitted to Global Change Biology.

Chen, J.M., W. Ju, J. Cihlar, D. Price, J. Liu, W. Chen, J. Pan, T.A. Black, and A.G. Barr. 2003. Spatial distribution of carbon sources and sinks in Canada's forests. Tellus 55B:622-641.

Griffis, T.J., T.A. Black, K. Morgenstern, A.G. Barr, Z. Nesic, G. Drewitt, D. Gaumont-Guay, and J.H. McCaughey. 2003. Ecophysiological controls on the carbon balances of three southern boreal forests. Agric. For. Met. 117: 53-71.

Griffis, T.J., T.A. Black, D. Gaumont-Guay, G. Drewitt, Z. Nesic, A.G. Barr, K. Morgenstern, and N. Kljun. Submitted. Seasonal variation and partitioning of ecosystem respiration in a southern boreal aspen forest. Submitted to Agric. For. Met.

Annex 2

Publications

Objective 6.2.1

Carbon Sequestration in a Boreal Deciduous Forest

Presentations

Barr, A.G., T.A. Black, K. Morgenstern, N. Kljun, T. Griffis, Z. Nesic and D. Gaumont-Guay. 2003. Inter-annual Variability in the Carbon and Water Balances of a Boreal Aspen Forest in Central Saskatchewan, 1994 to 2002. CMOS 37th Congress, Ottawa, ON, 2-5 June 2003.

Barr, A.G., T.A. Black, K. Morgenstern, N. Kljun, T. Griffis, Z. Nesic and D. Gaumont-Guay. 2003. Carbon Uptake in a Boreal Aspen Forest. 2003 Canadian Science Writers' Association Conference, June 9th, Saskatoon, SK.

Gaumont-Guay, D., T.A. Black, T. Griffis, N. Kljun, A. Barr, H. McCaughey, Z. Nesic and A. Sauter. 2003. Long-term chamber measurements of soil CO_2 efflux in the boreal forest. Poster presented to the Ameriflux Annual Meeting, October 2003, Boulder, Colorado.

Advice/ Coordination/ Assessment

Project: Advice/Coordination/Assessment

Publications

Hengeveld, H. 2000. Projections for Canada's Climate Future. CCD 00-01, Environment Canada.

Hengeveld,H. and Francis,D. 2000. Canadian climate models as windows to the future: How credible are they? CMOS Bulletin 28:111-116.

Hengeveld,H. 2000. Climate control report: The science. Alternatives Journal 26 (2):15-16.

Hengeveld,H. 2001. Climate change: Why all the fuss? Canadian Chemical News 53 (June):15-16.

Hengeveld, H. and Edwards, P. 2001. CO2/Climate Report Winter 2000, Environment Canada

Hengeveld, H. 2001. 1999 In Review: An Assessment of New Research Developments Relevant to the Science of Climate Change. CO2/Climate Report Spring 2001, Environment Canada.

Hengeveld, H.G. 2002. 2000 In Review: An Assessment of New Research Developments Relevant to the Science of Climate Change. CO2/Climate Report Winter 2002, Environment Canada.

Hengeveld,H., Kurz,W., Apps,M., Desjardins,R., Stocks,B., Stone,J. 2001. Scientific Perspectives re Biological Carbon Credits and the Global Carbon Cycle. Internal document, Environment Canada.

Hengeveld,H. 2002. Recent unusual weather and related impacts and disasters: Natural variability or climate change? CO2/Climate Report Fall 2002, Environment Canada.

Hengeveld,H, Bush,E. and Edwards,P. 2002. Frequently Asked Questions about the science of climate change. CCD 02-01. Environment Canada.

Hengeveld,H. 2002. Global Climate Change: Should Christian's be Concerned? Proc. Conference on Faith and Earthkeeping: Rebuilding a Value Framework for Action. www.caringforcreation.ca.

Hengeveld,H.G. 2003. Climate change and Canada's shipping lanes: The background science. In Ocean Yearbook (A. Chircop and M. McConnell, eds.), Volume 17:580-595. University of Chicago Press.

Hengeveld,H. 2003. The science behind Kyoto. Canada Research Horizons Vol 2 (spring 2002), page 9.

Hengeveld,H. 2003. Communicating complex science: Has the science community failed? CMOS Bulletin 31:71-76.

Hengeveld, H. 2003. 2001 In Review: An Assessment of New Research Developments Relevant to the Science of Climate Change. CO2/Climate Report Spring 2003, Environment Canada.

Hengeveld,H.G., Bush,E. and Edwards,P. 2003. Frequently asked questions about the science of climate change. Environment Canada.

Hengeveld, H. 2003. 2002 In Review: An Assessment of New Research Developments Relevant to the Science of Climate Change. CO2/Climate Report Spring 2003, Environment Canada.

Hengeveld,H. 2004. Chapter 8. Protection of the Atmosphere, with particular reference to North America. Encyclopedia of Life Support Systems, in Volume 50 (Lawrence Nkemdirim, ed.), Encyclopedia of Life Support Systems (EOLSS), Developed under the Auspices of the UNESCO, Eolss Publishers, Oxford ,UK, [http://www.eolss.net]

Hengeveld,H. (in preparation). Climate change - past, present and future. To be published in Part 3, Meteorology & Climatology (Assoc. ed., Tim Oke) of the Encyclopedia of Hydrological Sciences. Wiley Press, UK.

McBean, G.A. and Hengeveld, H.G. 2000. Communicating the science of climate change: a mutual challenge for scientists and educators. Can. J. Environmental Education 5:1-19.
Meteorological Service of Canada (EC) and Earth Science Sector (NRCan). 2002. Science & impacts of climate change: Presentation graphics and recent reports. CD-ROM format. Environment Canada and Natural Resources Canada.

Meteorological Service of Canada (EC) and Earth Science Sector (NRCan). 2002. Science & impacts of climate change: Presentation graphics and recent reports. CD-ROM format. Environment Canada and Natural Resources Canada.

Average of 20-30 presentations per year on climate change science to wide range of audiences.

Annex 3

Environment Canada Project Managers

ANNEX 3 ENVIRONMENT CANADA PROJECT MANAGERS

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POL 1.3.1

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POL 1.3.3

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POL 1.3.3 (Continued)

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Annex 4

List of Environment Canada's PERD Projects

ANNEX 4 LIST OF ENVIRONMENT CANADA'S PERD PROJECTS

POL #	Project Manager	Project Title	Email
POL 1.2.1	Offshore Environmental Factors (OEF)		
	Val Swail	Offshore Wind and Wave Design Criteria	Val.Swail@ec.gc.ca
	Lawrence Wilson	Data Assimilation into Coupled Atmosphere-Ocean Wave Models	Laurie.j.Wilson@ec.gc.ca
	Tom Carrieres	Operational Ice Modeling	Tom.Carrieres@ec.gc.ca
	Dean Flett	Operational Detection of Icebergs from Space-Borne SAR	Dean.flett@ec.gc.ca
POL 1.2.2	Northern Hydrocarbon Production		
	Laura Johnston	Minimizing Environmental Risk from Petroleum Exploration in the Lower Mackenzie River Valley of the Northwest Territories	Laura.Johnston@ec.gc.ca
POL 1.2.3	Marine Transportation and Safety (MTS)		
	Tom Carrières	Prediction of Small Glacial Mass Distributions	Tom.Carrieres@ec.gc.ca
POL 1.3.1	Flaring Research Initiative (FRI)		
	Bill Reynen	PTAC Steering Committee	Bill.Reynen@ec.gc.ca
	Alka Steenkamer	Strategic Planning, Policy Integration and Management	Alka.steenkamer@ec.gc.ca
POL 1.3.3	Soil and Groundwater Remediation		
	John Headley	Natural Wetlands - Containment, Transformation and Remediation of Toxic Organics from Natural Gas Condensates and Process Chemicals	John.Headley@ec.gc.ca
	John Headley	Remediation of Naphthenic Acids in Subsurface Soils and Groundwater at Oil Refineries	John.Headley@ec.gc.ca
	Bill Reynen	Groundwater Research Program	Bill.Reynen@ec.gc.ca
	Dale Van Stempvoort	The Role of Sulfate Reduction in the Bioremediation Technologies for Hydrocarbon Contamination in Groundwater	Dale.VanStempvoort@ec.gc.ca
	Bill Reynen	Remediation of Hydrocarbon-Contaminated Sites by Monitored Natural Attenuation	Anne-marie.thompson@ec.gc.ca
	Terry McIntyre	Assessment of Phytoremediation as an In-Situ Technique for Cleaning Oil Contaminated Sites	Terry.McIntyre@ec.gc.ca
	Nathalie Ross and Suzanne Lesage	Biological Barriers in Fractured Bedrock	Nathalie.Ross@ec.gc.ca Suzanne.Lesage@ec.gc.ca
	Carl Brown	Solar Detoxification of Groundwater	Carl.Brown@ec.gc.ca
	Carl Brown	In-Situ Soil Flushing for the Remediation of Hydrocarbon Contaminated Soil	Carl.Brown@ec.gc.ca
	Nathalie Ross	Attenuation of an Ethanol/BTEX Plume in Fractured Bedrock Model Undergoing Biostimulation	Nathalie.Ross@ec.gc.ca
	Richard Scroggins	Standardization and Validation of Terrestrial Toxicity Test Procedures for Assessing Biological Effects in Hydrocarbon Contaminated Soils	Rick.Scroggins@ec.gc.ca
	Kevin Cash	Assessment of Natural and Anthropogenic Impacts of Oil Sands Contaminants within the Northern River Basin	Kevin.Cash@ec.gc.ca
	Terry McIntyre	Land Farming of Bioremediated Hydrocarbon Contaminated Soils/Wastes	Terry.McIntyre@ec.gc.ca

POL #	Project Manager	Project Title	Email
POL 1.3.3	Soil and Groundwater Remediation (Continued)		
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	Saviz Mortazavi and Alka Steenkamer	POL Planning and Management, POL Planning Workshop	Saviz.Mortazavi@ec.gc.ca Alka.steenkamer@ec.gc.ca
	Alka Steenkamer	Departmental Support	Alka.steenkamer@ec.gc.ca
POL 2.1.1	Support for the Development of Technological and Other Measures to Control and Reduce Emissions of Particulate Matter (Air Quality- Particles Research)		
	Lisa Graham	Characterization of Particulates and Precursors in Emission	Lisa.graham@ec.gc.ca
	Jeff Brook	Characterization of Particles in Ambient Air	Jeff.Brook@ec.gc.ca
	Alka Steenkamer	Strategic Planning, Policy Integration and Management	Alka.steenkamer@ec.gc.ca
POL 2.1.2	Advanced Fuels and Transportation Emissions Reduction (AFTER)		
	Fred Hendren	Engine Cold Start Efficiency	Fred.Hendren@ec.gc.ca
	Greg Rideout	Windsor Workshop Support	Greg.Rideout@ec.gc.ca
	Greg Rideout	Measurement of Toxic Emissions from Ethanol/Gasoline Blend Emissions	Greg.Rideout@ec.gc.ca
	Merv Fingas	Environmental Properties of Ether Fuels	Merv.Fingas@ec.gc.ca
POL 2.2.2	Fuel cells, Electric and Hybrid Vehicles		
	Greg Rideout	Measurement of Toxic Emissions from Fuel Cells, Electric, and Hybrid Vehicles	Greg.Rideout@ec.gc.ca
POL 2.2.4	Optimization of the Energy Efficiency of Transportation Systems		
	Normand Michaud	The St Lawrence Routing Management Support Model	Normand.Michaud@ec.gc.ca
POL 3.2.4	Energy Management for Sustainable Communities		
	Dennis Jackson and Alain David	Development of energy from waste technologies and other alternative technologies: -Microturbines Development/Emission Research from Landfill Gas Improvement of Waste Management Decision-Making:: -Integrated Waste Management (IWM) Model -Advanced Landfill Technology	Dennis.Jackson@ec.gc.ca Alain.David@ec.gc.ca
	Frank Cruickshanks	Seasonal Energy Storage	Frank.Cruickshanks@ec.g
	Franck Portalupi	Clean Air Online	Franck.Portalupi@ec.gc.ca
	Brad Bass	Integrating Urban Forestry, Green Roofs and Vertical Gardens to Reduce Energy Consumption	Brad.Bass@ec.gc.ca
POL 4.3.3	Research, Development and Deployment for Industrial Separation and Refrigeration (SEPREF)		
	Jocelyn Paré	Applications of Microwave-Assisted Process (MAPTM) to Solvent-less Synthesis and to Low Solvent, Energy-Efficient Extraction	Jocelyn.Pare@ec.gc.ca
POL 5.1.1	Electricity from Renewable Energy Technologies		
	Bruce McArthur Robert Morris	EC: Wind and Solar Energy Resource Assessment - Solar Radiation	Bruce.McArthur@ec.gc.ca Robert.Morris@ec.gc.ca
	Robert Benoit and Robert Morris	Wind Mapping with Atmospheric Models	Robert.Benoit@ec.gc.ca Robert.Morris@ec.gc.ca

List of Environment Canada's PERD Projects

Annex 4

POL #		Project Manager	Project Title
POL 5.2.1	Characterization of Canadian Fuels and their Emissions (COFE)		
	Don Rose	Environmental Contaminants in Coal and Coal Byproducts	Donald.Rose@ec.gc.ca
POL 5.2.2	Clean and Efficient Combustion Technologies for Large Utility Electricity Generation		
	Don Rose	Prevention, Control and Mitigation of Pollution from Stationary Combustion Sources	Donald.Rose@ec.gc.ca
POL 5.2.3	CO_2 Capture and Storage		
	Bill Reynen	Coal Bed Methane Field Pilot- Characterization of Injected CO_2 and Impact on CBM	Bill.Reynen@ec.gc.ca
POL 6.1.1	Climate Change Impacts on the Energy Sector (CCIES)		
	Don MacIver	Historical and Future Climate for the Assessment of Energy Sector Impacts in Canada	Don MacIver@ec.gc.ca
	Gérald Vigeant Jean-Claude Therriault (DFO)	Impacts of Climate Changes in the Canadian Inland Seas Watershed on the Canadian Energy Sector	Gérald.Vigeant@ec.gc.ca therriaultjcsci@dfo-mpo.gc.ca
	Val Swail	Climate Change and Offshore Design Criteria	Val.Swail@ec.gc.ca
	Tom Agnew	Impacts of Evolving Ice Conditions on the Energy Sector-completed in 2001	Tom.agnew@ec.gc.ca
	Tom Agnew and Tom Carrières	Critical Aspects of Changes in Sea Ice Cover on Energy Production	Tom.agnew@ec.gc.ca Tom.carrieres@ec.gc.ca
	George Isaac	Canadian Participation in FIRE III/SHEBA	George.Isaac@ec.gc.ca
	Terry Prowse Philip Marsh	Climate Change Impacts on Cold-Regions Hydrologic Processes and Extreme Events Associated with the Hydro-Electric and Oil/Gas Industries in Western and Northern Canada	Terry.Prowse@ec.gc.ca Philip.Marsh@ec.gc.ca
	Kit Szeto	Critical Aspects of the Climate of Western Canada for the Energy Industry	Kit.Szeto@ec.gc.ca
	Anne Walker	Snow Water Equivalent Variations in Western Canada and Climate Change Related Impacts for Hydropower Production	Anne Walker@ec.gc.ca
	Sunling Gong	Changes in Cloud Cover over North America for Solar Energy Development in Canada	Sunling.Gong@ec.gc.ca
	Heather Auld and Brad Bass and Joan Klaassen	Climate and Energy in the Toronto-Niagara Region(-Integration of Science and Policy)	Heath.Auld@ec.gc.ca Brad.Bass@ec.gc.ca Joan.Klaassen@ec.gc.ca
POL 6.2.1	Enhancement of Greenhouse Gas Sinks (EGGS)		
	Kaz Higuchi	Estimation of Terrestrial CO_2 Sources and Sinks in Canada	Kaz.higuchi@ec.gc.ca
	Rick Bourbonnière	Wetlands in the Forest Context-Carbon Sink Potential	Rick.bourbonniere@ec.gc.ca
	Alan Barr	Impact of Variability and Climate Change on Carbon Sequestration in a Boreal Deciduous Forest	Alan.barr@ec.gc.ca
	Rick Bourbonnière	Wetlands in the Agricultural Context-Carbon Sink Potential	Rick.bourbonniere@ec.gc.ca
	Henry Hengeveld	Advice/Coordination/Assessment	Henry.Hengeveld@ec.gc.ca
	Alka Steenkamer	Strategic Planning, Policy Integration and Management	Alka.steenkamer@ec.gc.ca